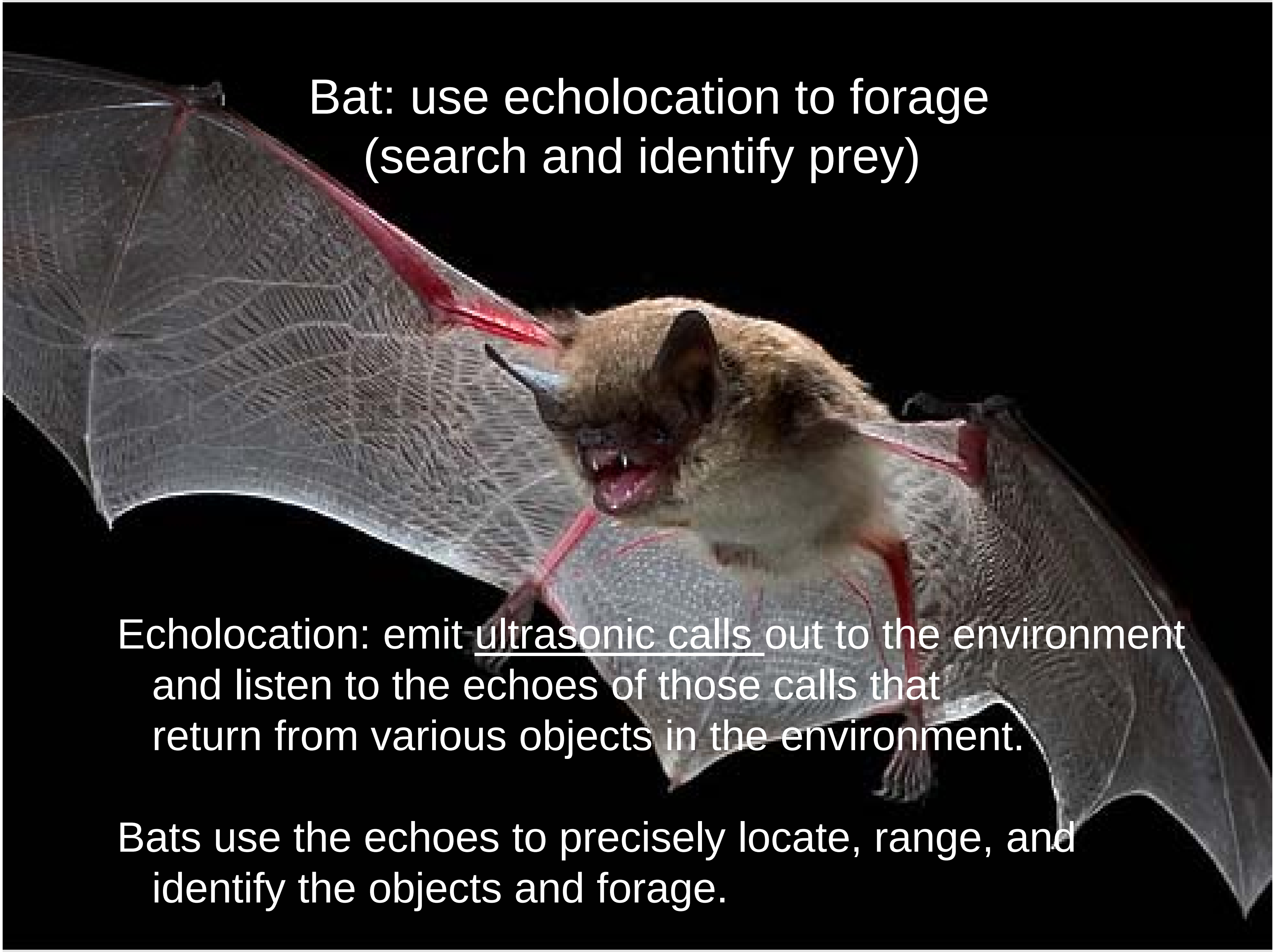
Foraging behavior

Foraging strategy

Foraging strategy I

Echolocation

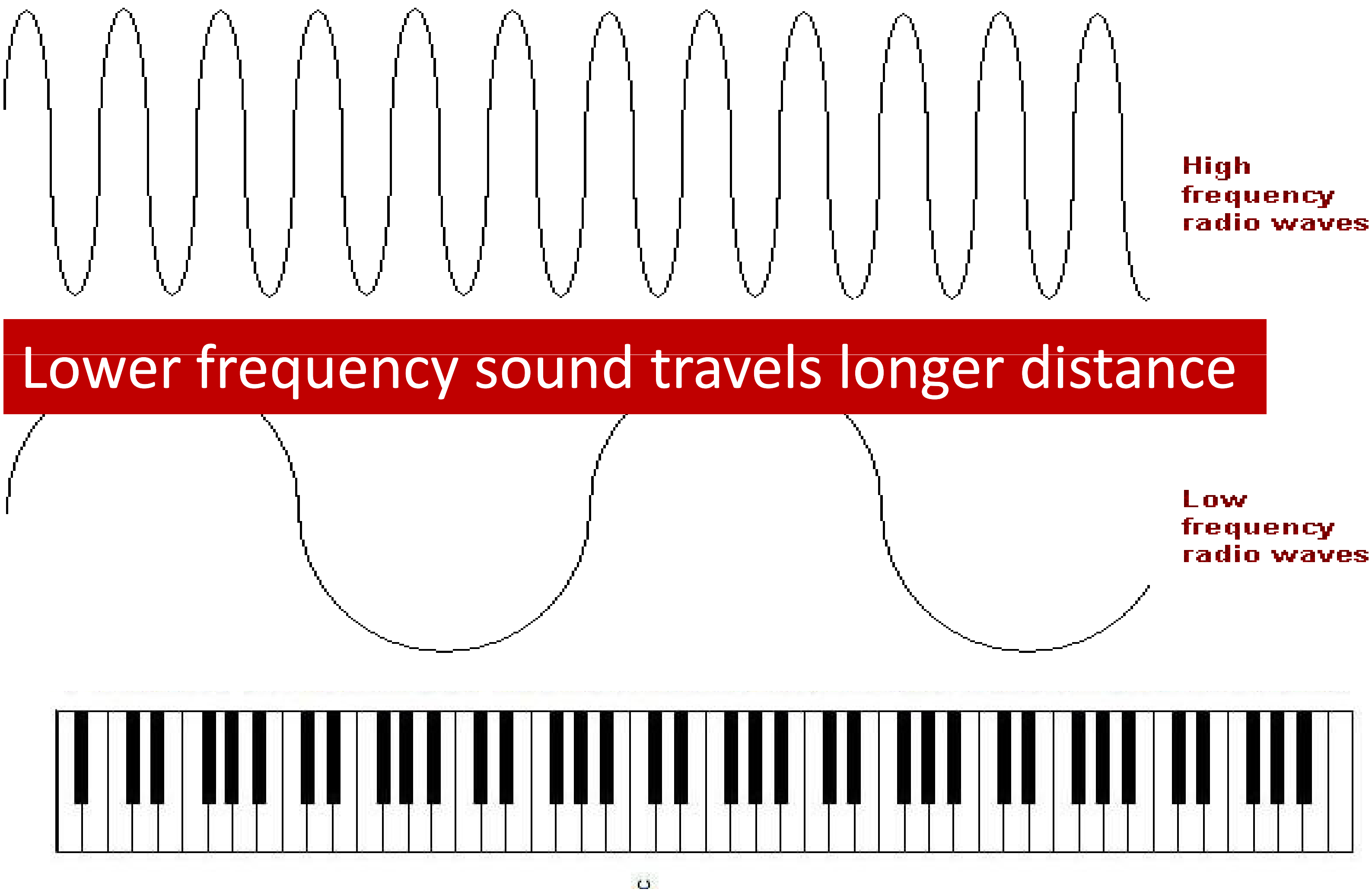
Bat: use echolocation to forage (search and identify prey)



Echolocation: emit ultrasonic calls out to the environment and listen to the echoes of those calls that return from various objects in the environment.

Bats use the echoes to precisely locate, range, and identify the objects and forage.

Sound, sound frequency, and sound travel distance



Sound, sound frequency, and sound travel distance

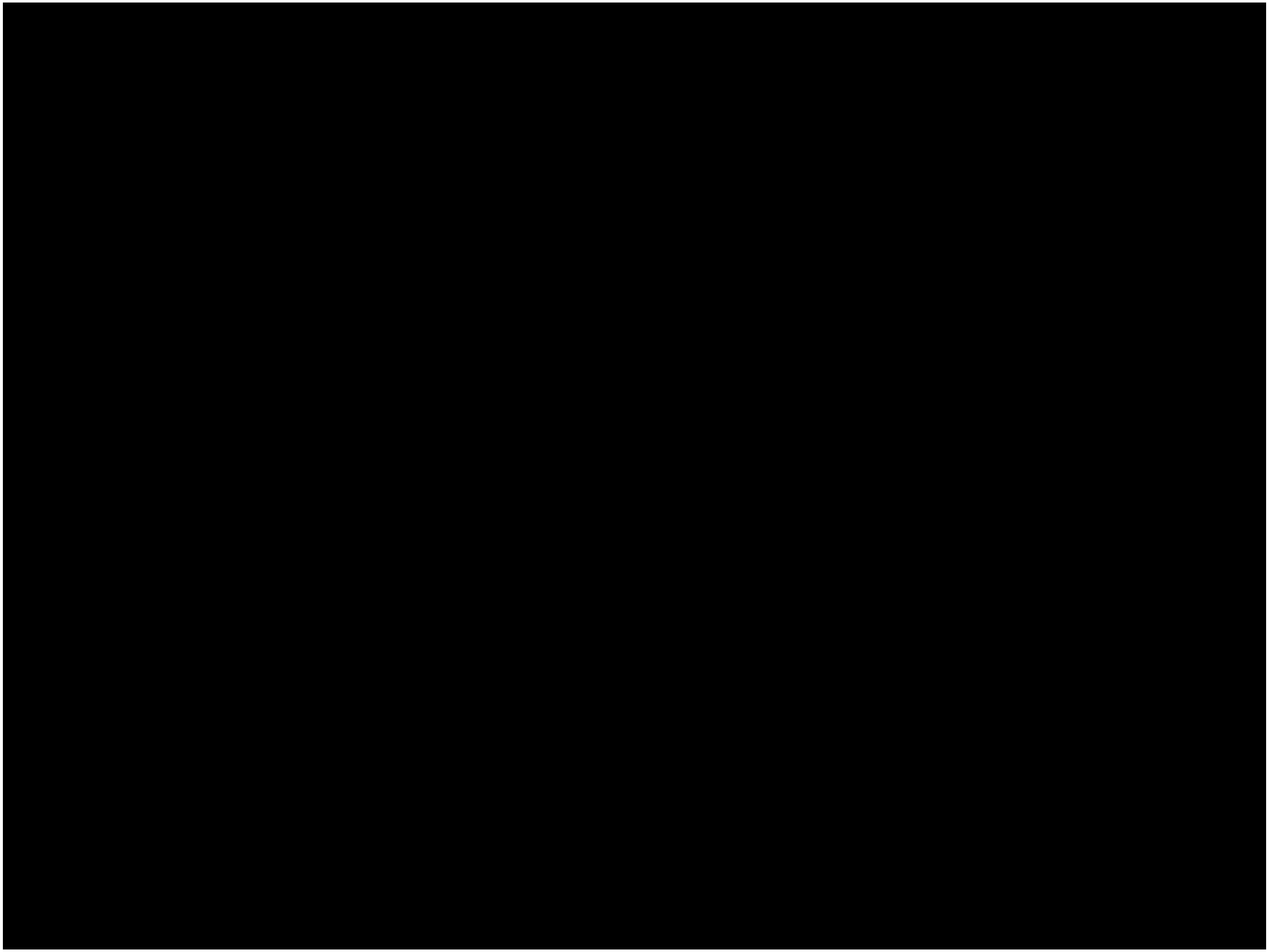
Specific sound frequency can break wine glass

Bats produce ultrasound: 14,000 to well over 200,000 Hz, why so high freq?

and very loud: 120 dB.

S. No	Classification	Range	Description	Applications
1	Infra sound	0.1Hz to 25Hz	Short frequency sounds	Infrasound can travel a long distance over 3 km. Therefore, helpful for long distance communication, used by elephants.
2	Audible sound	20Hz to 20kHz	Medium frequency sounds	Human hearing
3	Ultrasound	> 20kHz	High frequency sounds	Ultrasound travels only a short distance. Therefore, helpful for short distance target detection within 10m, used by bats.

Infrasound of whales



Ultrasounds of various bat species

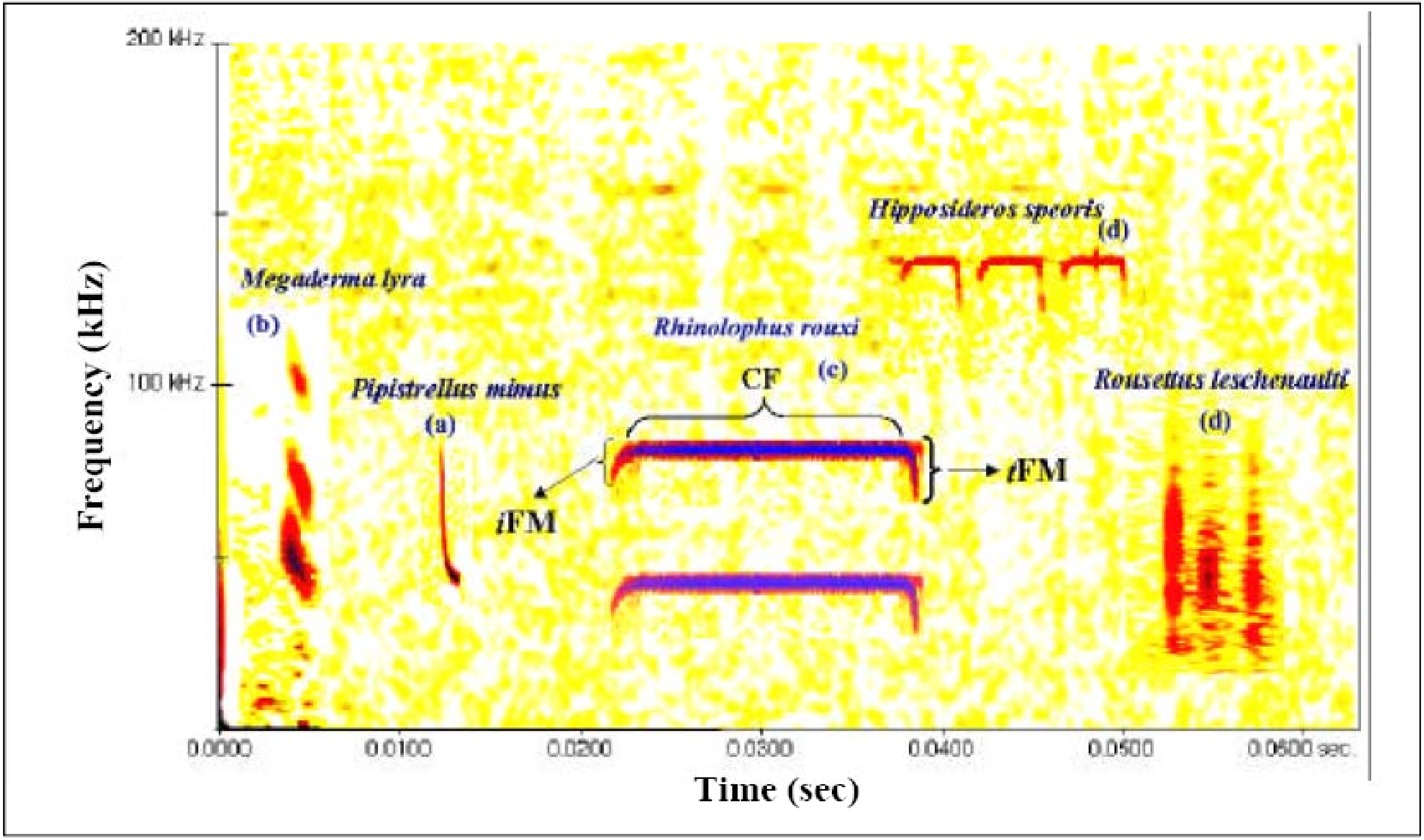


Figure 3. Sonagram representation of echolocation calls of different south Indian bat species. (a)

Why do bats have big ears?

Echolocation in bats

discovered by Donald Griffin
at Rockefeller University

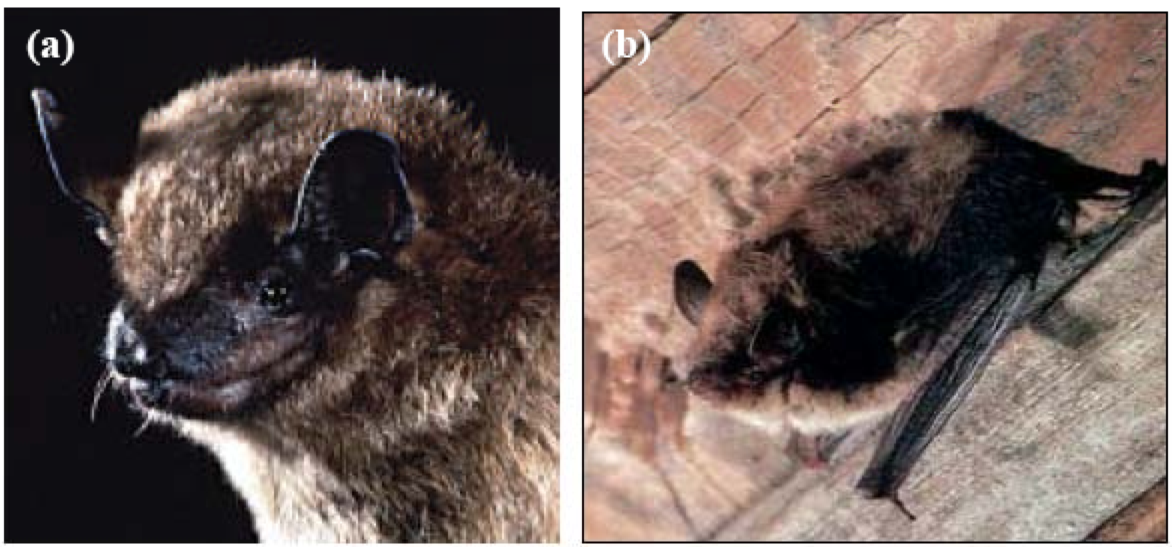


Figure 1. Bat species first used to study echolocation (a) Eptesicus fuscus (big brown bat), (b) Myotis lucifugus (little brown bat). (Photo credit: Merlin Tuttle, BCI)

Echolocation in bats

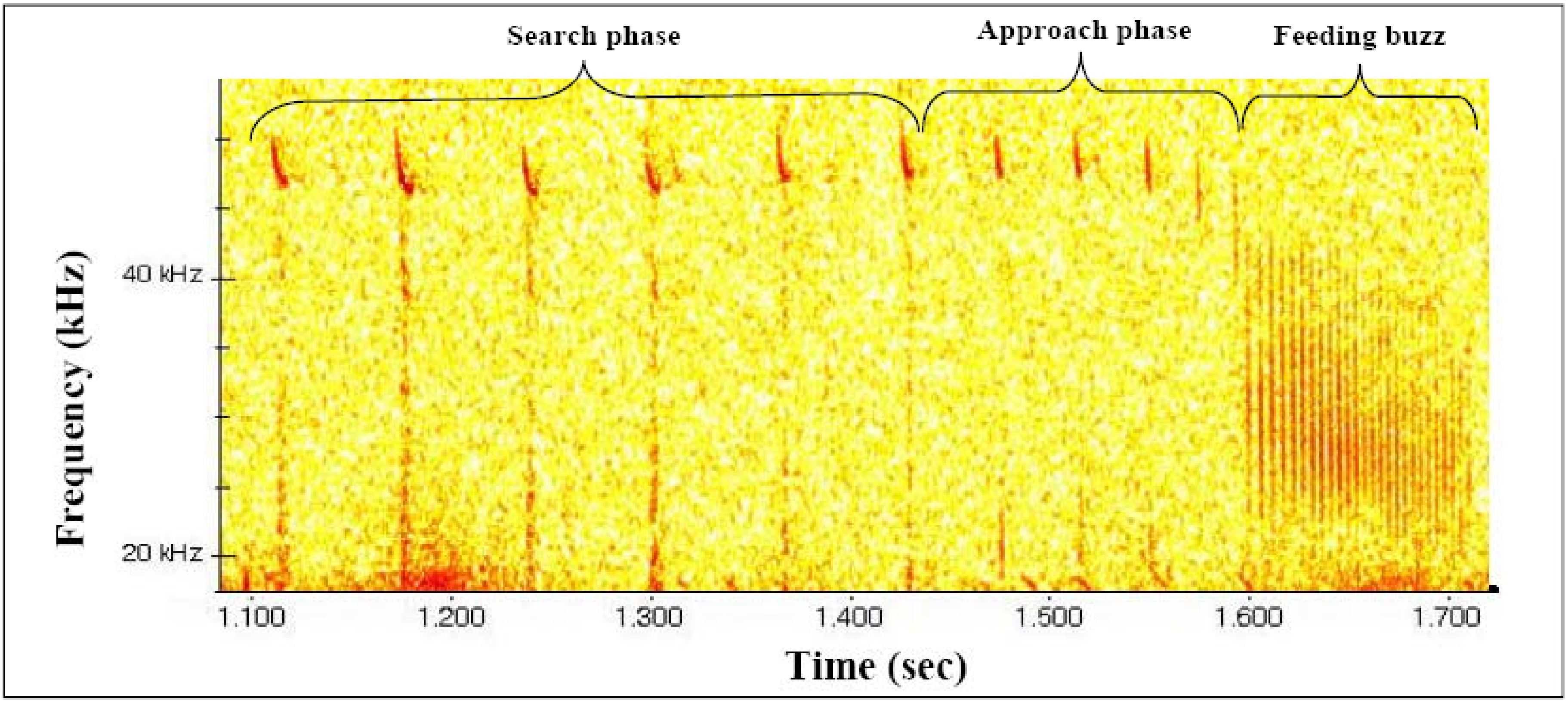
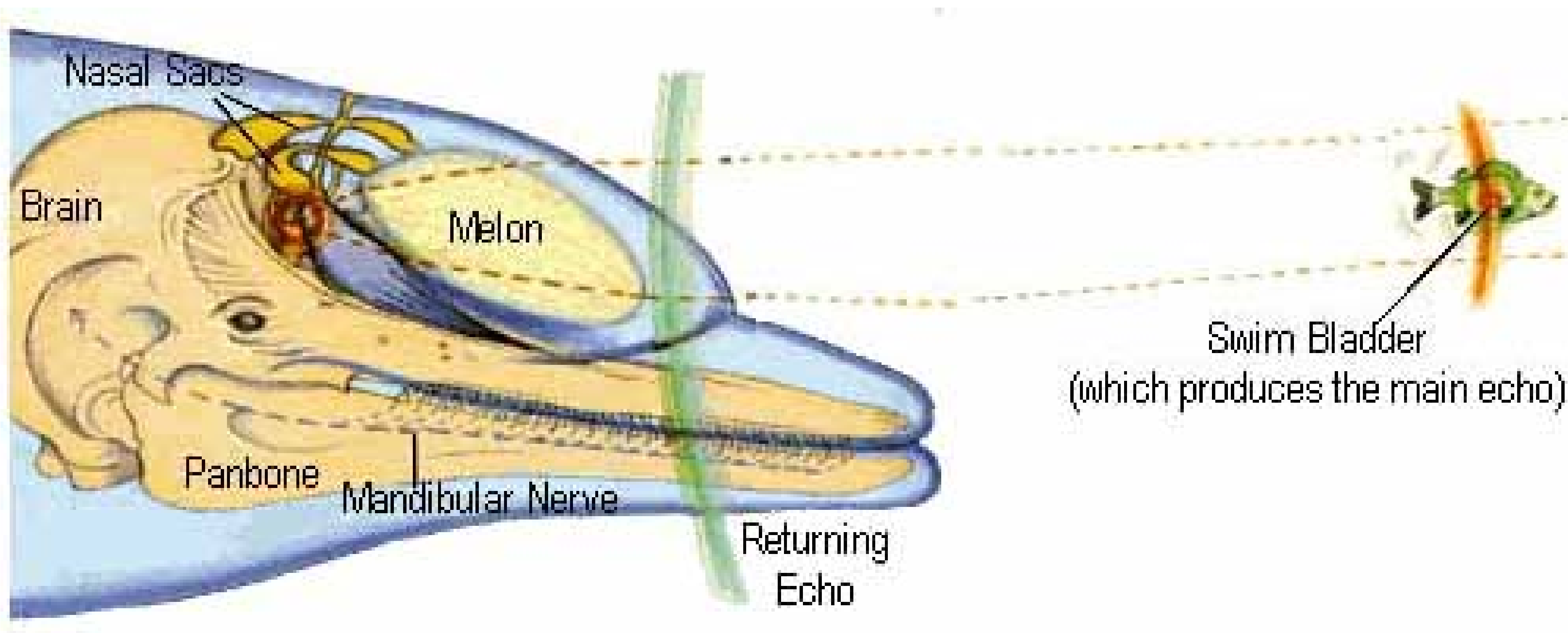
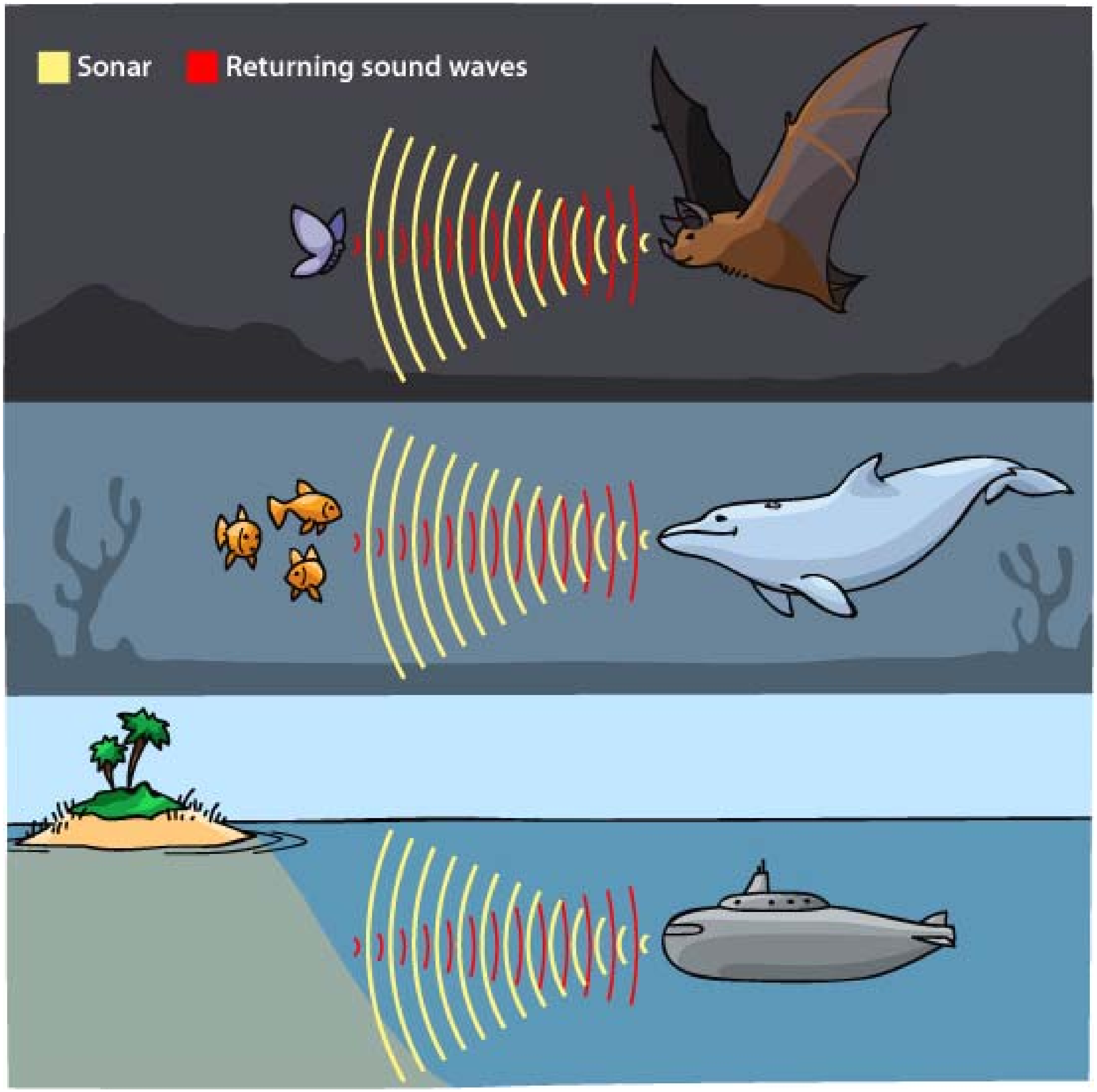


Figure 4. Echolocation call sequence of Pipistrellus mimus during prey capture recorded near a street lamp during winter. Note the changes in interpulse interval during search, approach and capturing phase (feeding buzz or terminal buzz).

Echolocation in Dolphins

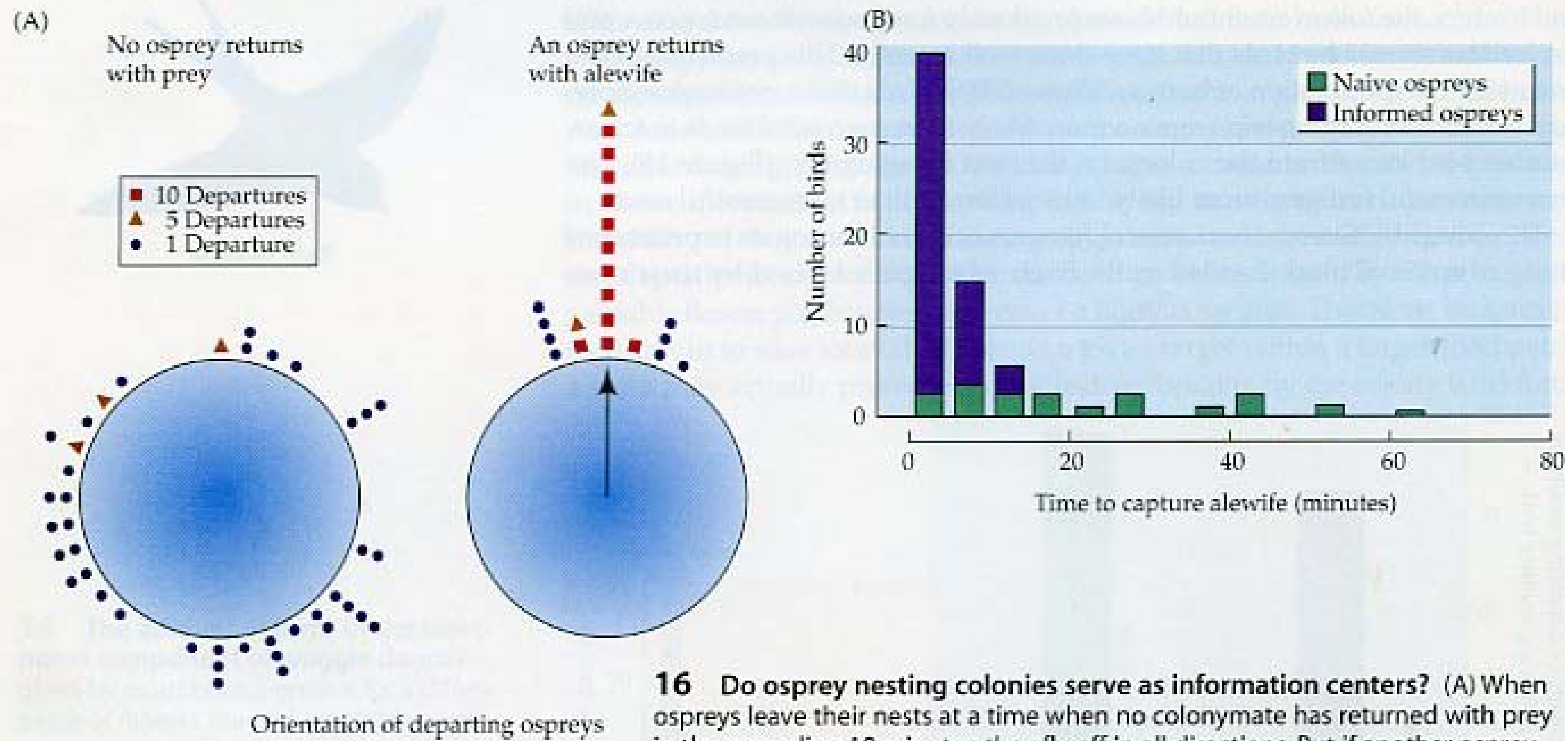



Sonar
Returning sound waves

Foraging strategy II

Information provided by companions


Ospreys use information from others



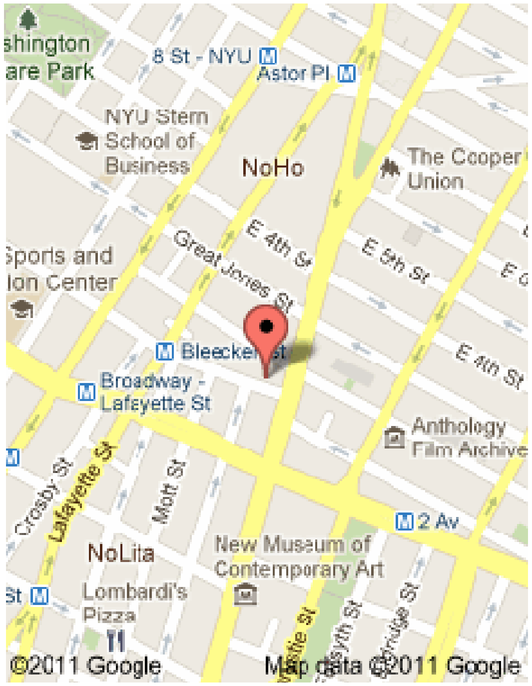
16 Do osprey nesting colonies serve as information centers? (A) When ospreys leave their nests at a time when no colonymate has returned with prey in the preceding 10 minutes, they fly off in all directions. But if another osprey has come back with an alewife (a schooling fish), the departing birds tend to fly off in the same direction (represented by an arrow) as the successful hunter. (B) Naive ospreys (those that have not seen a prey-carrying colonymate prior to departure) take much longer to find alewife schools than informed ospreys (those that have just observed a returning neighbor carrying an alewife in its talons). After Greene [455].

Foraging strategy II

Information provided by companions

(symbolic language)

Bianca Restaurant
5 Bleecker St., New York, NY 10012
nr. Bowery See Map | Subway Directions
212-260-4666 Send to Phone
•**Cuisine:** Italian
•**Price Range:**$$
•**Reader Rating: 9** out of 10



Honey bees foraging

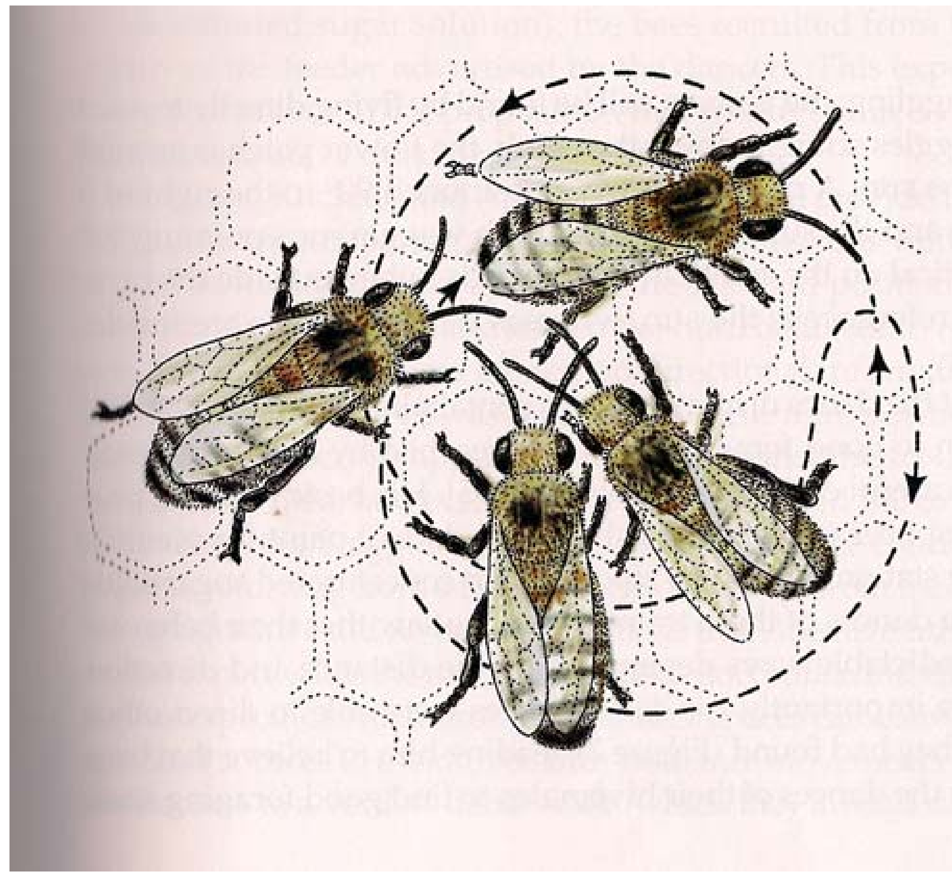
Foraging worker bees perform dance when they return to the hive after having found a good source of pollen or nectar.

Dances contain a lot of information abut the location and distance of the food source.

Honey bee dance

1.Round dance

food source is <50 meters

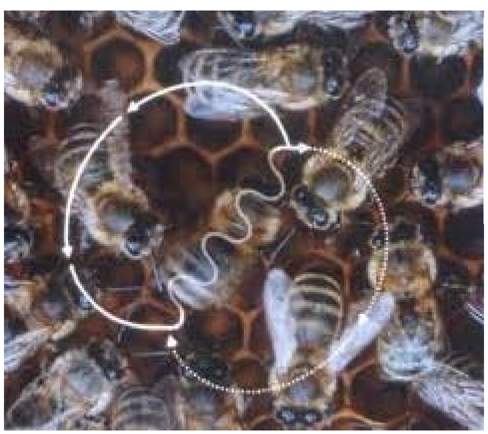


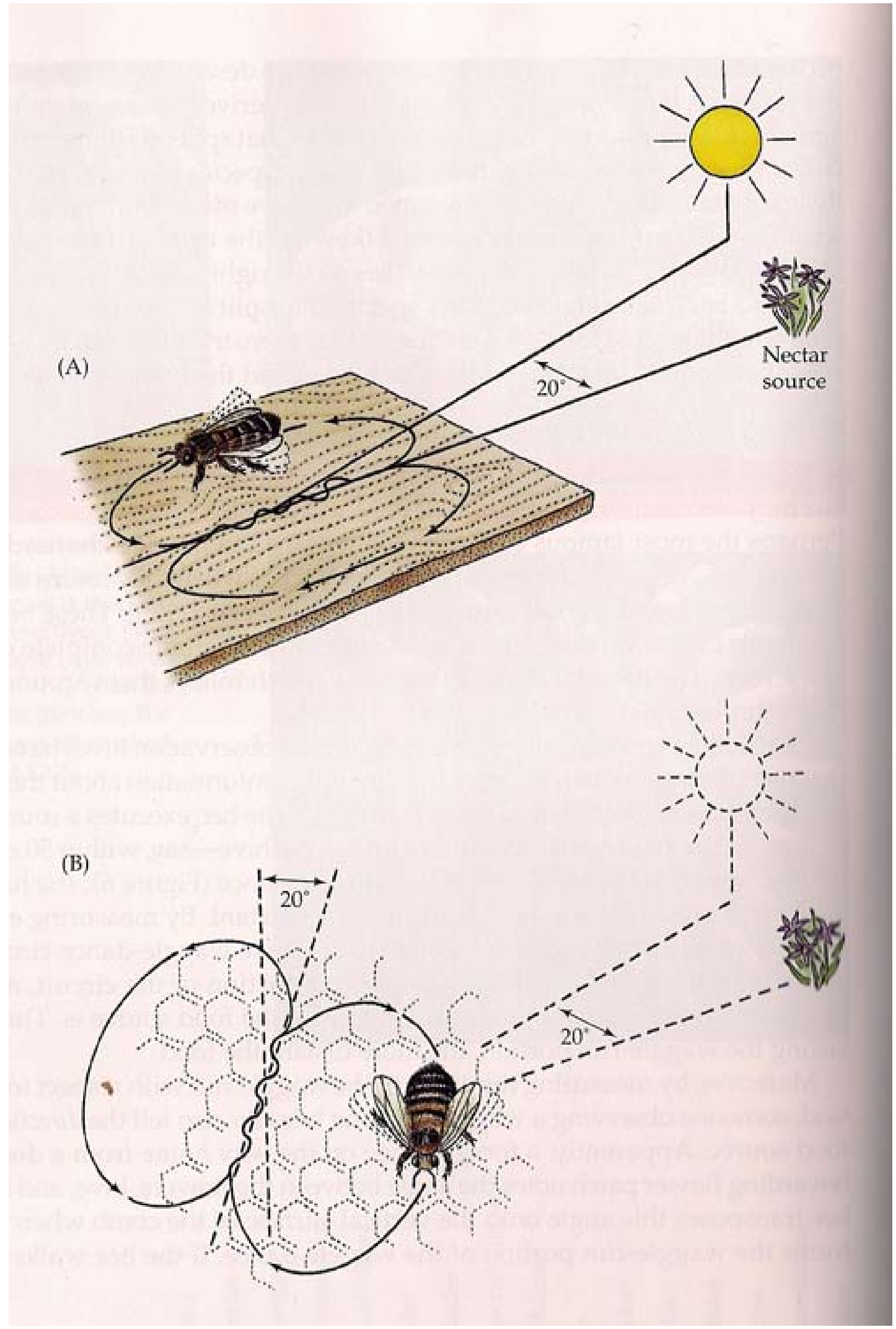
2. Waggle dance

food source is >50 meters

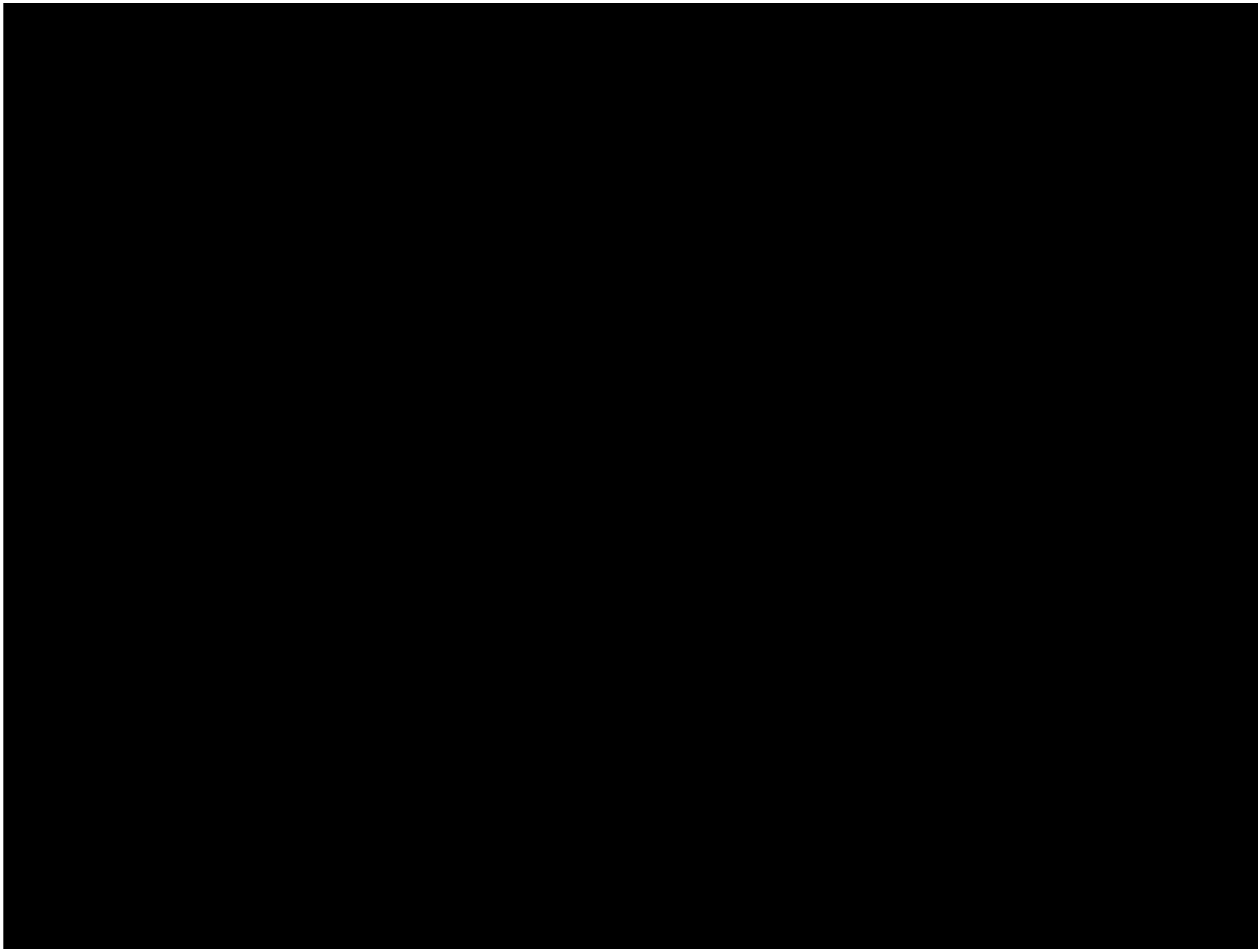
3. Angle of the dance:

direction to the food source.





Waggle dance



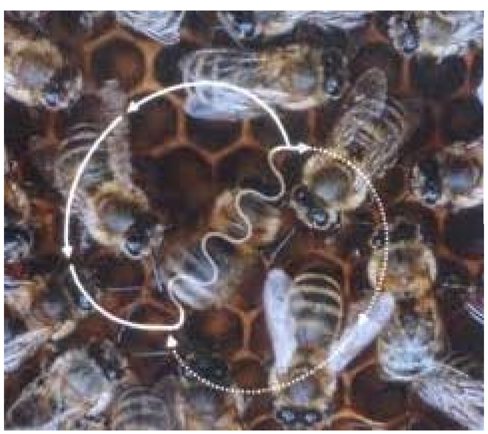
The more circles the bee dances, the further the food source

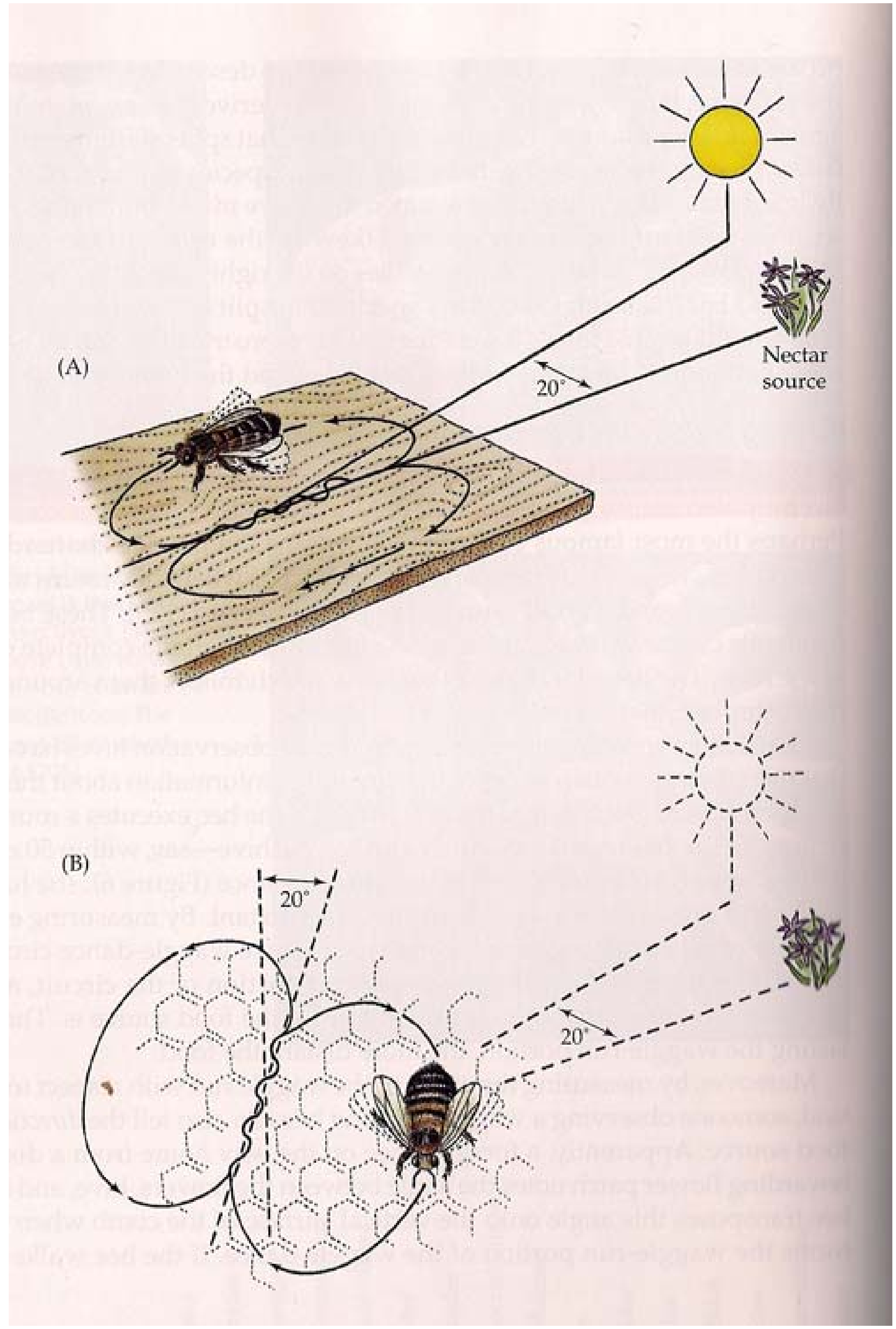
2. Waggle dance

food source is >50 meters

3. Angle of the dance:

direction to the food source.





Proximate mechanism of honeybee (worker) foraging

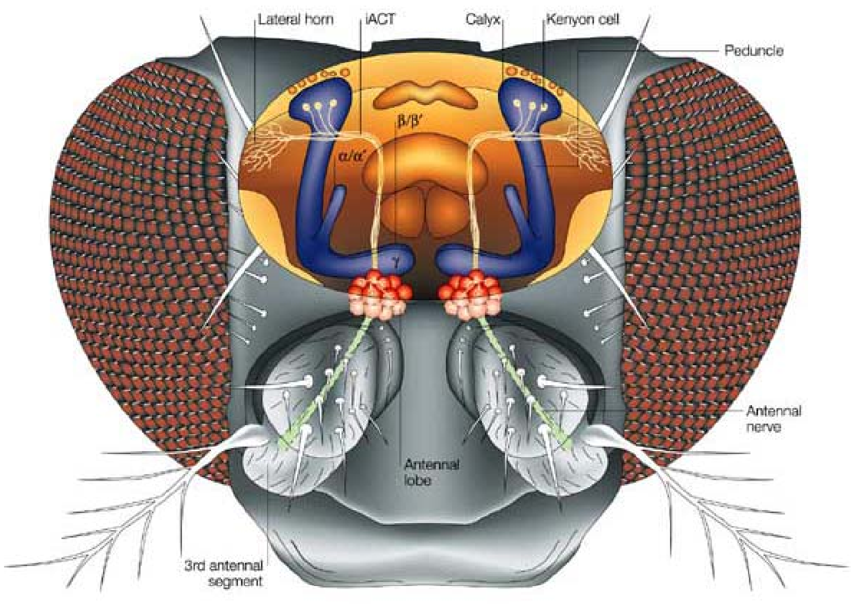
Honeybee workers

(lifespan=1month)

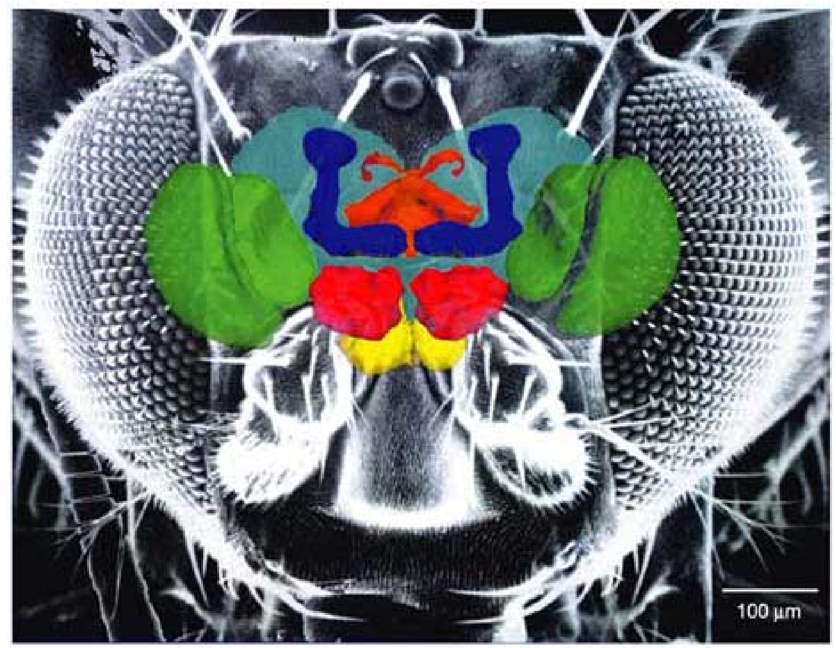
1. Hatch ~ 2,3 weeks old:
   Nursing bees (sitters)

2. Then head out, become foragers
   → a brain area "mushroom bodies" grows
   → hormone (JH) increases
   → a gene *"for"* (foraging) turns on

Mushroom bodies and honeybee foraging



Nature Reviews | Neuroscience

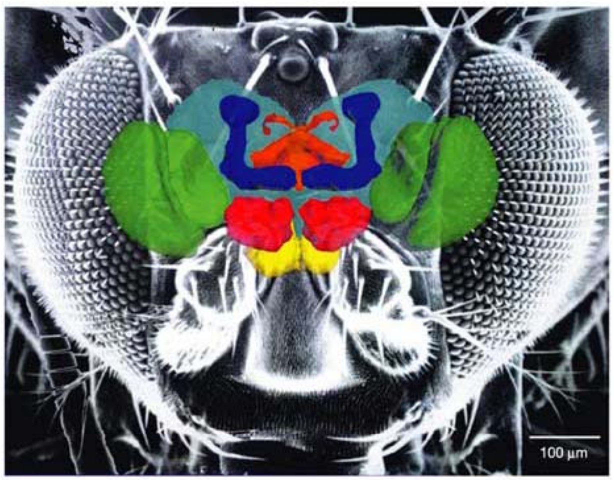


Nature Reviews | Neuroscience

Mushroom bodies – spatial navigation and memory.

Forager workers have significantly larger (15%) mushroom bodies than younger nursing bees.

Correlation between Mushroom body size and honeybee foraging behavior



Nature Reviews | Neuroscience

The growth of mushroom bodies (because of age) causes foraging behavior?

Or foraging causes the size of Mushroom bodies increases?

Design an experiment to test the cause-effect?

Experimentally remove the mushroom bodies

Or,

Induce the foraging behavior in younger bees

2. Hormone mechanisms of honeybee foraging

As bees mature into foragers that leave the nest, the level of Juvenile Hormone (JH) significantly increases.

Correlation between *JH* hormone level and honeybee foraging behavior

Higher *JH* hormone level causes foraging behavior?

Or foraging behavior causes the higher level of juvenile hormone?

How do you conduct an experiment to test the cause-effect?

Experimentally remove the gland that produces *JH.*

Or

Induce the foraging behavior in younger bees

3. Gene associated with honeybee foraging

As bees mature into foragers that leave the nest, "*For*" (forage) gene turns on.

Correlation between *"For"* gene turn-on and honeybee foraging behavior

Turning on of *"For"* gene causes foraging behavior?

Or foraging behavior causes the "*For*" gene turns on ?

How do you design an experiment to test cause-effect?

Experimentally "knock-out" the "For" gene.
Or
Induce the foraging behavior in younger bees

Foraging strategy III

Deceiving prey

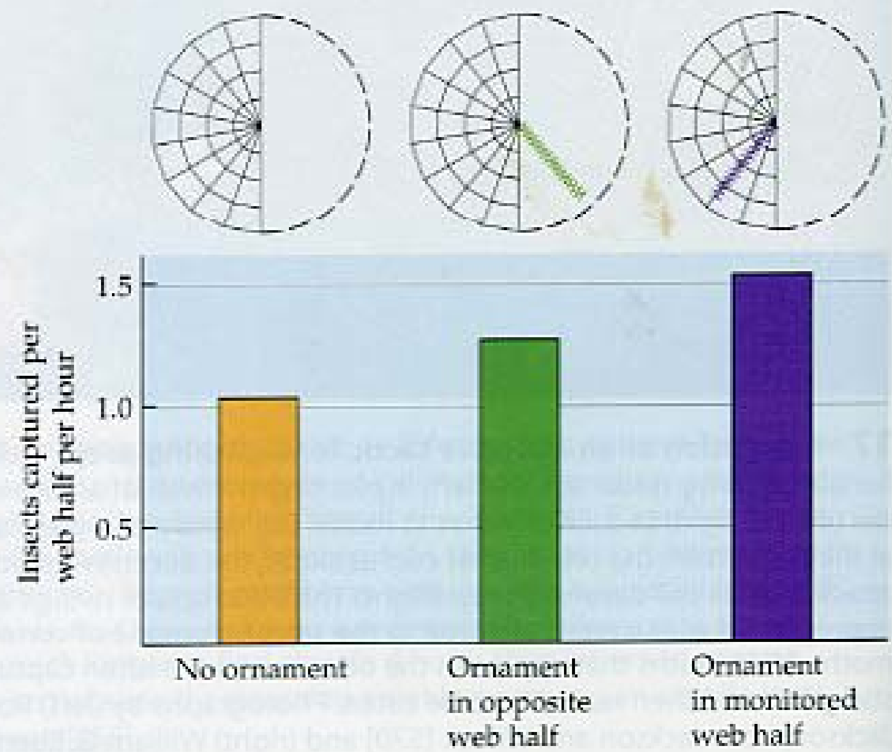
Locating prey by deceit

17 Deception as an adaptive tactic for capturing prey. (Left) A juvenile female jumping spider (on the left) is plucking the web of an orb-weaving spider (on the right) in such a way as to mimic the signals of a prey item trapped in the web. When the orb-weaver comes closer, the deceptive predator will attack and kill the deceived prey. (Right) The bolas spider swings its lure, a ball impregnated with a scent identical to the sex pheromone of certain female moths. Male moths that approach the odor source are often captured by the sticky ball and then reeled in to be eaten. Photographs by (left) Robert Jackson, from Jackson and Wilcox [570] and (right) William G. Eberhard.

Orb-weaving spider

Ultraviolet-reflecting silk

Locating prey by deceit



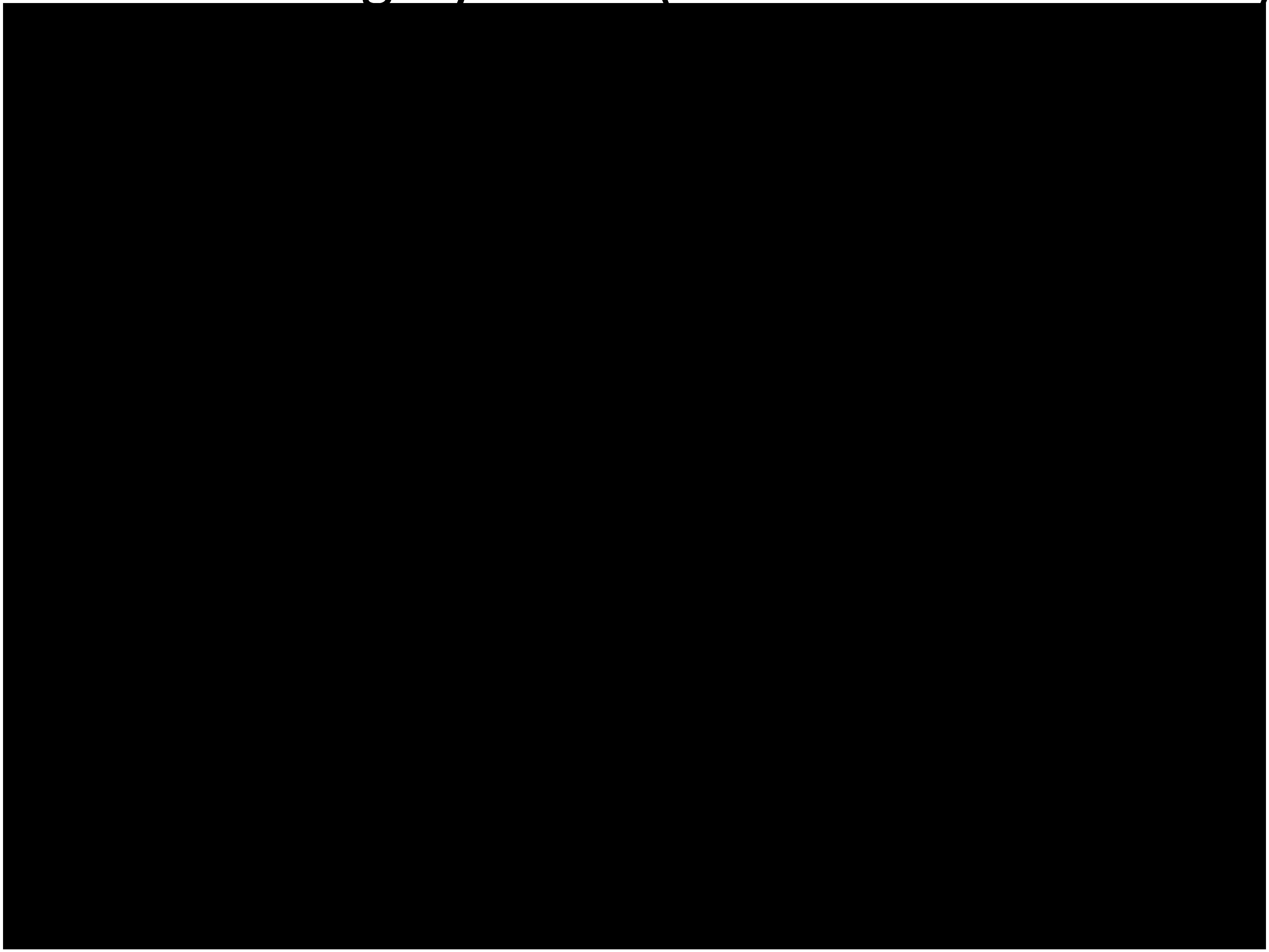
19 Do web ornaments lure prey? Garden spider webs without ultraviolet-reflecting ornaments capture fewer prey per hour than those containing ornaments. Furthermore, in webs with only one ornament, more flying insects are trapped in the half of the web containing the ornament than in the half lacking these structures. After Craig and Bernard [251].

Foraging strategy:

Food caching

Food caching by Squirrels

Food caching by birds (New Zealand Robins)



Food caching in birds

Common in Corvidae (crows, jays)
and Paridae (tits, chickadees)
-- both groups stay winter in the North

Why do these birds cache food?
1) Adapt to environment: winter, unpredictable food
2) Phylogenetic effect:

Food caching by Clark's Nutcracker

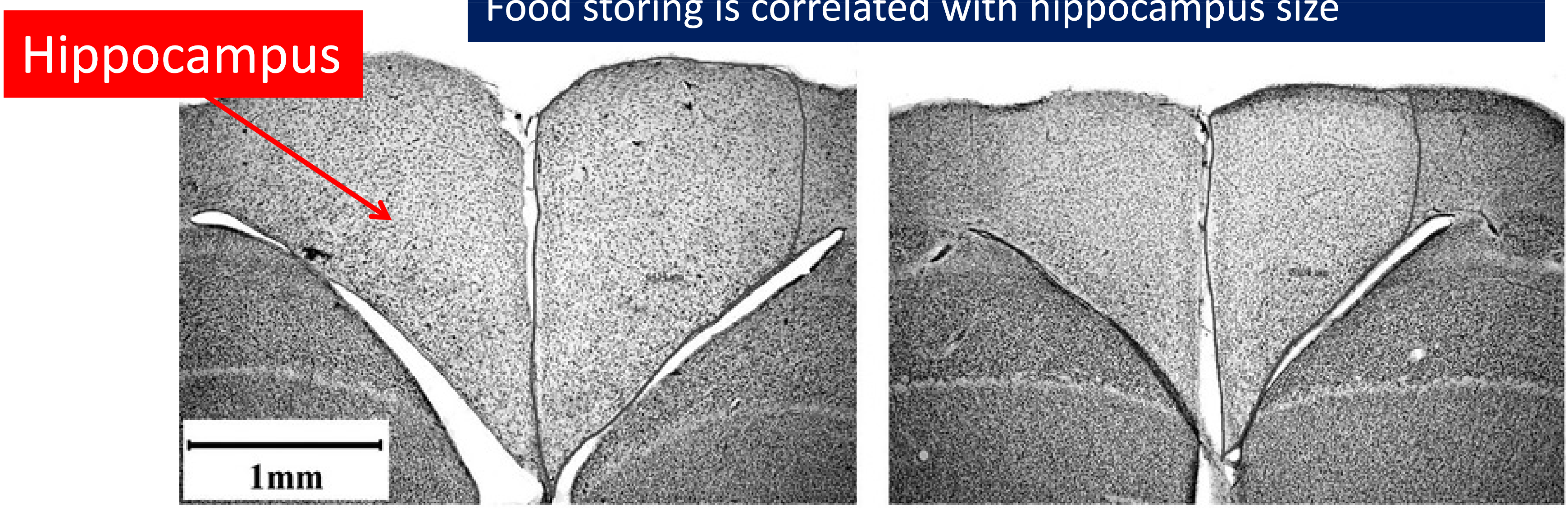
Cache ~98,000 seeds
per season

Remarkable long-term spatial memory;
relocate caches of seeds with
remarkable accuracy,
nine months later, and even
when the cache sites are buried
under up to a meter (3 ft) of snow

Food caching requires good memory → Hippocampus

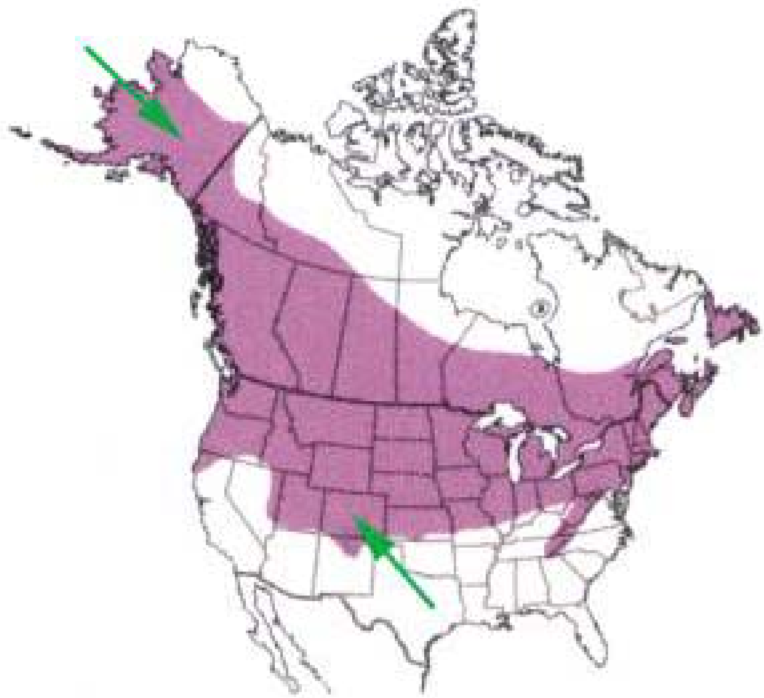
1. The more food-storing behavior seen in a species→ the greater the hippocampal volume.

Wild, free-ranging birds store food, but captive birds don't. Food storing is correlated with hippocampus size



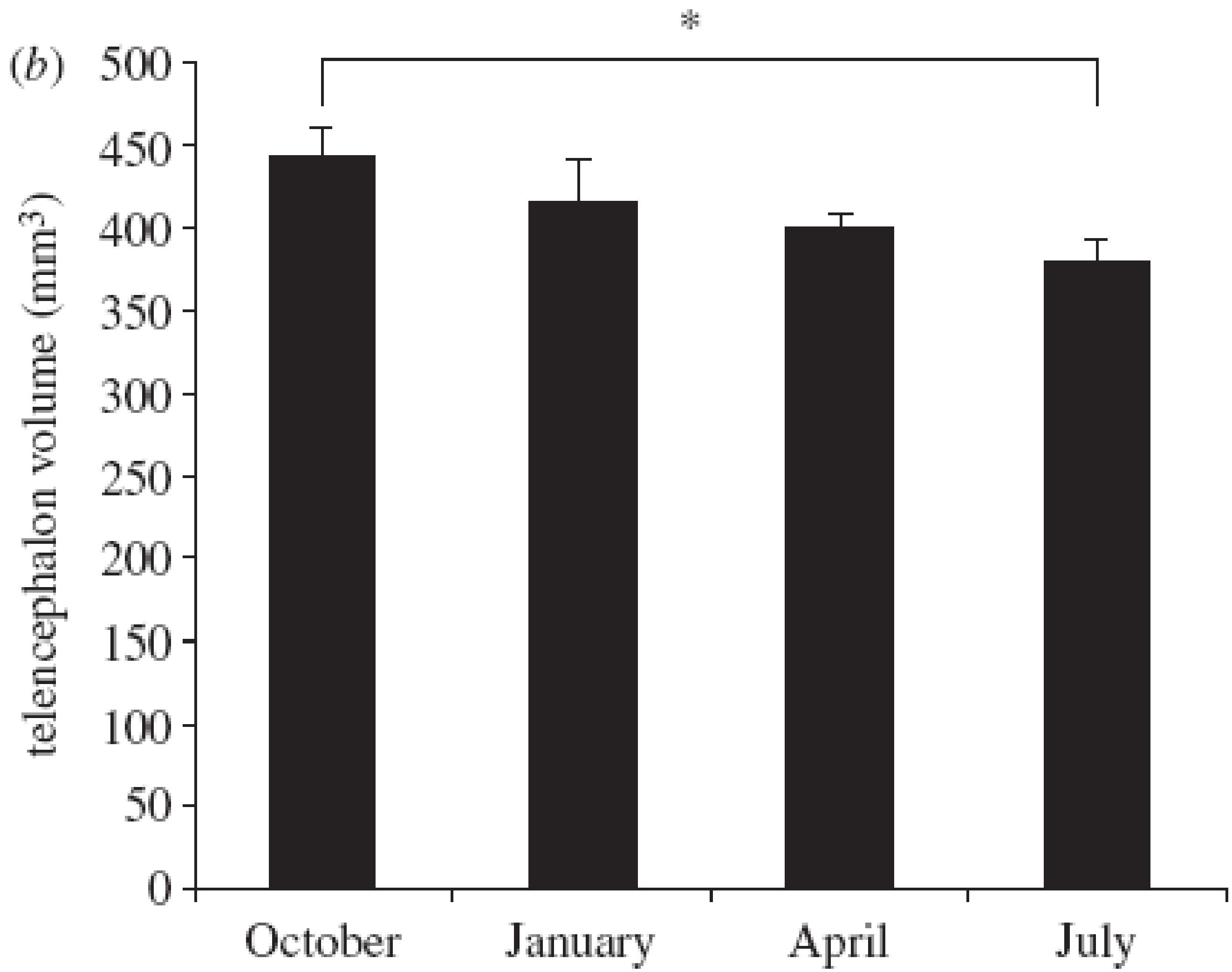
Wild Bird Captive Bird

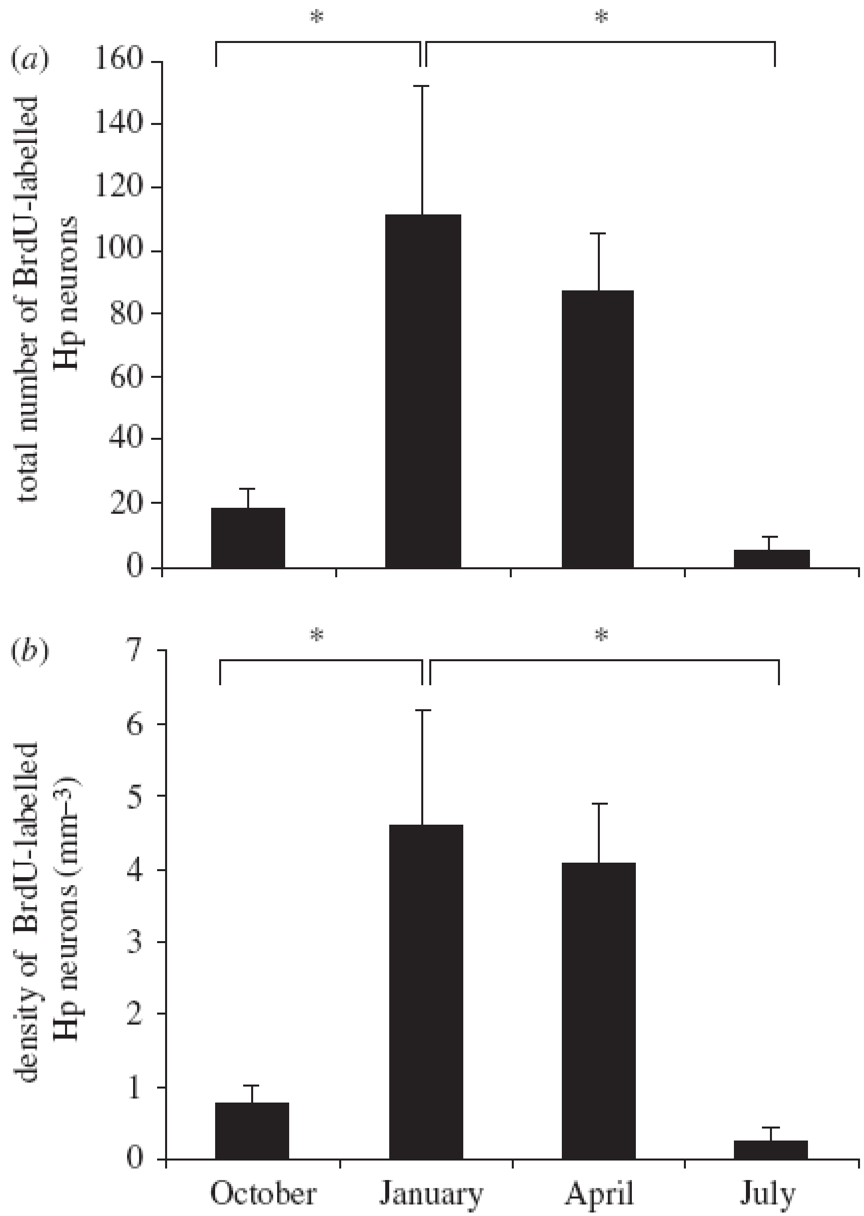
Differences in memory and the hippocampus between northern and southern populations of a food-storing species, the black-capped chickadee.



Black-capped chickadees living in Alaska cache more food, are more efficient at cache recovery, perform more accurately on spatial memory tasks and have larger hippocampal volumes than black-capped chickadees that live in Colorado.

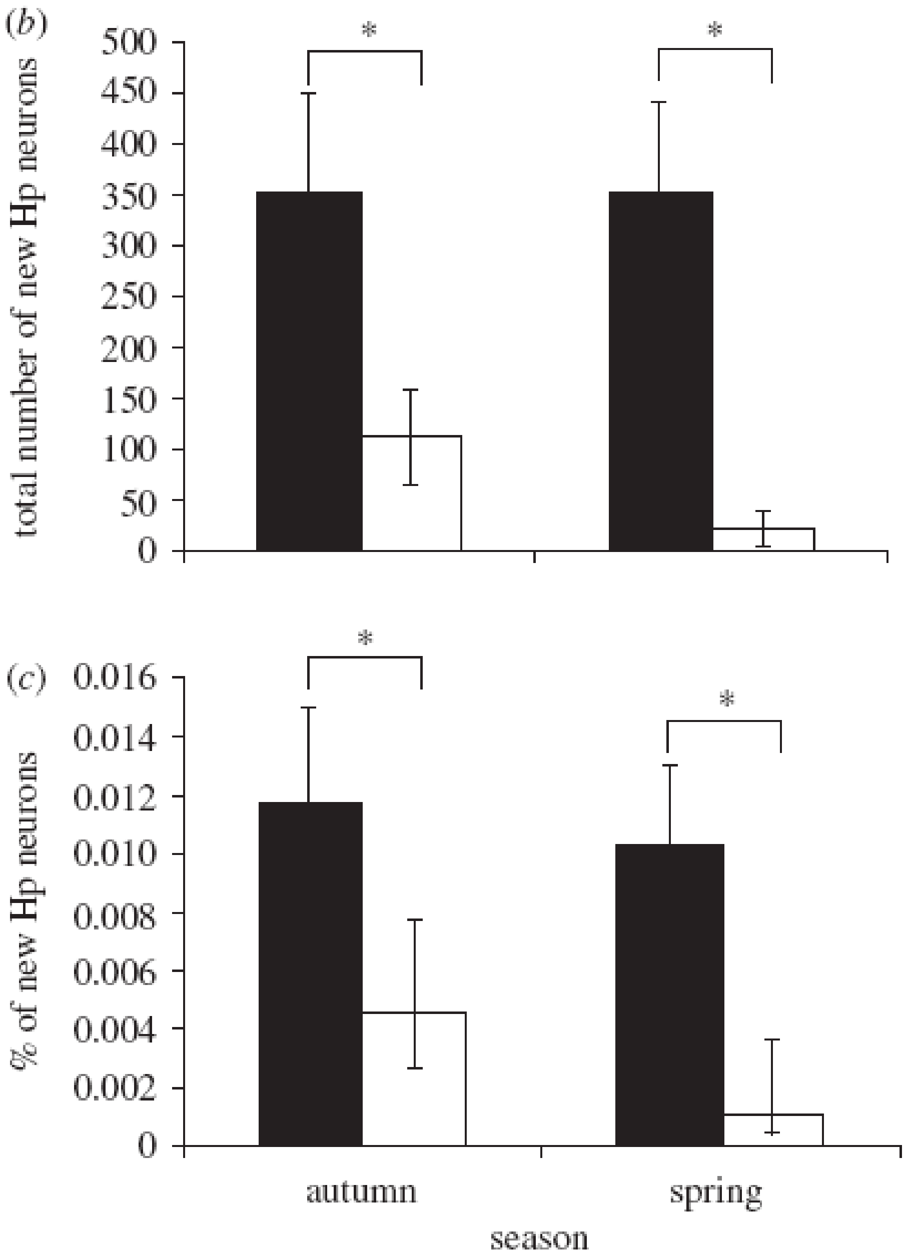
Forebrain grows bigger during the peak period of food caching





Hippocampus grows more new neurons when chickadees retrieve food

Do non-storing birds grow new neurons?



Hippocampus grows more new neurons in food-storing (black bar) chickadees than non-storing sparrows (white bar).

Re-caching food when others jays are around

1. Observations: Scrub jays watch where conspecifics have cached, pilfering them when given the opportunity.

2. Hypothesis 1: Scrub jays adjust their own caching strategies to minimize potential pilfering. (anti-pilfering strategy)

3. Predictions

Jays would be more likely to re-cache, and specifically in new sites unknown to an observer, but only if they had been watched during the caching trial.

4. Experimental designs:

Scrub jays were allowed to cache either in private (when the other bird's view was obscured) or while a conspecific was watching, and then recover their caches in private.

5. Results

birds re-cached significantly more items during recovery when they had been observed during caching.

Table 1 Behaviour of the observer + pilferer birds during observed and in private caching treatments

	Caching treatment		Wilcoxon pairs test		
Behaviour	Observed	In private	*n*	*Z*	*P*
No. cached					
Davis	8.19 ± 1.55	4.71 ± 0.81	7	2.37	<0.05
Cambridge	10.48 ± 3.43	9.10 ± 3.05	7	0.51	>0.5
No. recovered					
Davis	4.61 ± 0.93	3.95 ± 0.84	7	0.85	>0.1
Cambridge	5.38 ± 1.56	4.19 ± 1.10	7	0.08	>0.5
Proportion recovered					
Davis	0.71 ± 0.06	0.57 ± 0.07	7	2.03	<0.05
Cambridge	0.56 ± 0.08	0.70 ± 0.09	7	1.69	>0.05
Recovery accuracy*					
Davis	2.21 ± 0.46	3.21 ± 1.01	7	1.15	>0.1
Cambridge	3.07 ± 0.92	1.52 ± 0.24	7	1.36	>0.1
No. re-cached					
Davis	2.19 ± 0.68	0.57 ± 0.32	7	2.20	<0.05
Cambridge	2.74 ± 1.01	0.36 ± 0.19	7	2.20	<0.05
Proportion re-cached					
Davis	0.44 ± 0.20	0.06 ± 0.03	7	2.20	<0.05
Cambridge	0.28 ± 0.07	0.08 ± 0.04	7	2.20	<0.05

3. Anti-pilfering strategy is more likely to happen if an individual was a pilferer in the past.

1. Observations: Scrub jays adjust their own caching strategies to minimize potential pilfering. (anti-pilfering strategy)

2. Hypothesis II: Anti-pilfering strategy may require the experience of being a pilferer in the past.

3. Predictions:

Pilfer (had experience of pilfering) would re-cache while a conspecific was watching, and then recover their caches in private. Observer (no experience of pilfering) would not re-cache to new sites.

4. Experimental designs

Birds in the pilferer group had the opportunity to listen to, but not observe, another bird caching, and were then allowed to pilfer those caches. As all the birds had received extensive caching experience, they readily searched for caches even when they had not seen the storer hide food.

These birds do not have the opportunity to observe conspecifics caching in these experiments, but have the experience of pilfering.

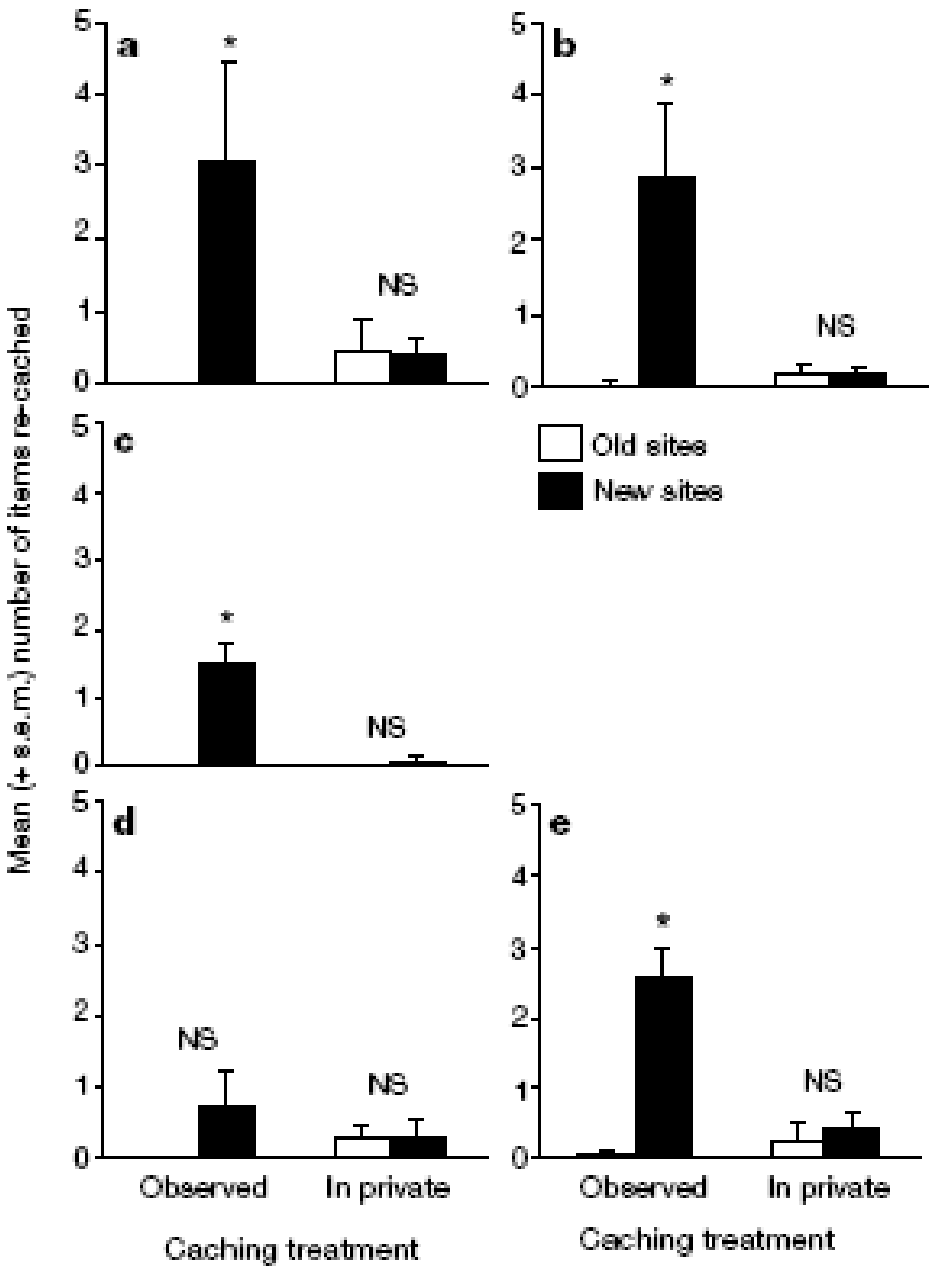
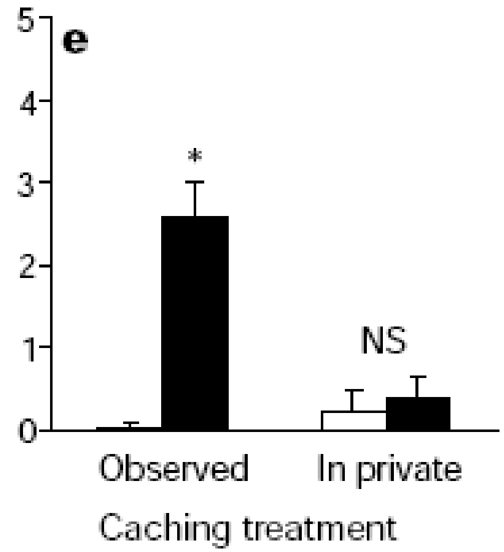


Figure 1 Mean (+ s.e.m.) number of worms re-cached by the three groups. **a**, The observer + pilferer group in Davis re-cached significantly more in the new sites during the observed caching treatment ($n = 7$, $Z = 2.20$, $P < 0.05$), but failed to discriminate between new and old sites during the in private caching treatment ($n = 7$, $Z = 0$, $P = 1.0$). **b**, The observer + pilferer group in Cambridge also re-cached significantly more in new sites when observed during caching ($n = 7$, $Z = 2.20$, $P < 0.05$), but again did not discriminate between re-caching in old or new sites during the in private caching treatment (no statistical comparison possible). **c**, The observer + pilferer group also selectively re-cached food in new sites in the observed tray ($n = 7$, $Z = 2.37$, $P < 0.05$), but did not discriminate between old and new sites in the in private tray during the interleaved caching trials (no statistical comparison possible). **d**, The observer group did not selectively re-cache in either new or old sites during both the observed and the in private caching treatments (old: $n = 7$, $Z = 1.6$, $P > 0.1$; new: no statistical comparison possible). **e**, The pilferer group re-cached significantly more food items in new sites during the observed caching treatment ($n = 7$, $Z = 2.37$, $P < 0.05$), but as with the observer + pilferer group, did not re-cache selectively in either old or new sites during the in private caching treatment (no statistical comparison possible). All analyses were Wilcoxon matched-pairs tests. Asterisk, $P < 0.05$, NS, not significant ($P > 0.05$).

5. Result

pilferer group re-cached more items during recovery if they had been observed during caching, and predominantly in new sites.



6. Conclusion: the results are consistent with the predictions, thus they support the hypothesis that jays need experience of being a pilfering to know when to re-cache.

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Summary

1. Anti-pilfering strategy is dependent on social contexts (presence of conspecifics).

2. Great memory: recall the specific tray in which they cached while being watched,

3. Need experience of being a pilferer to know when to re-cache. Not require experience of observing a con-specific hide food.

Implications:

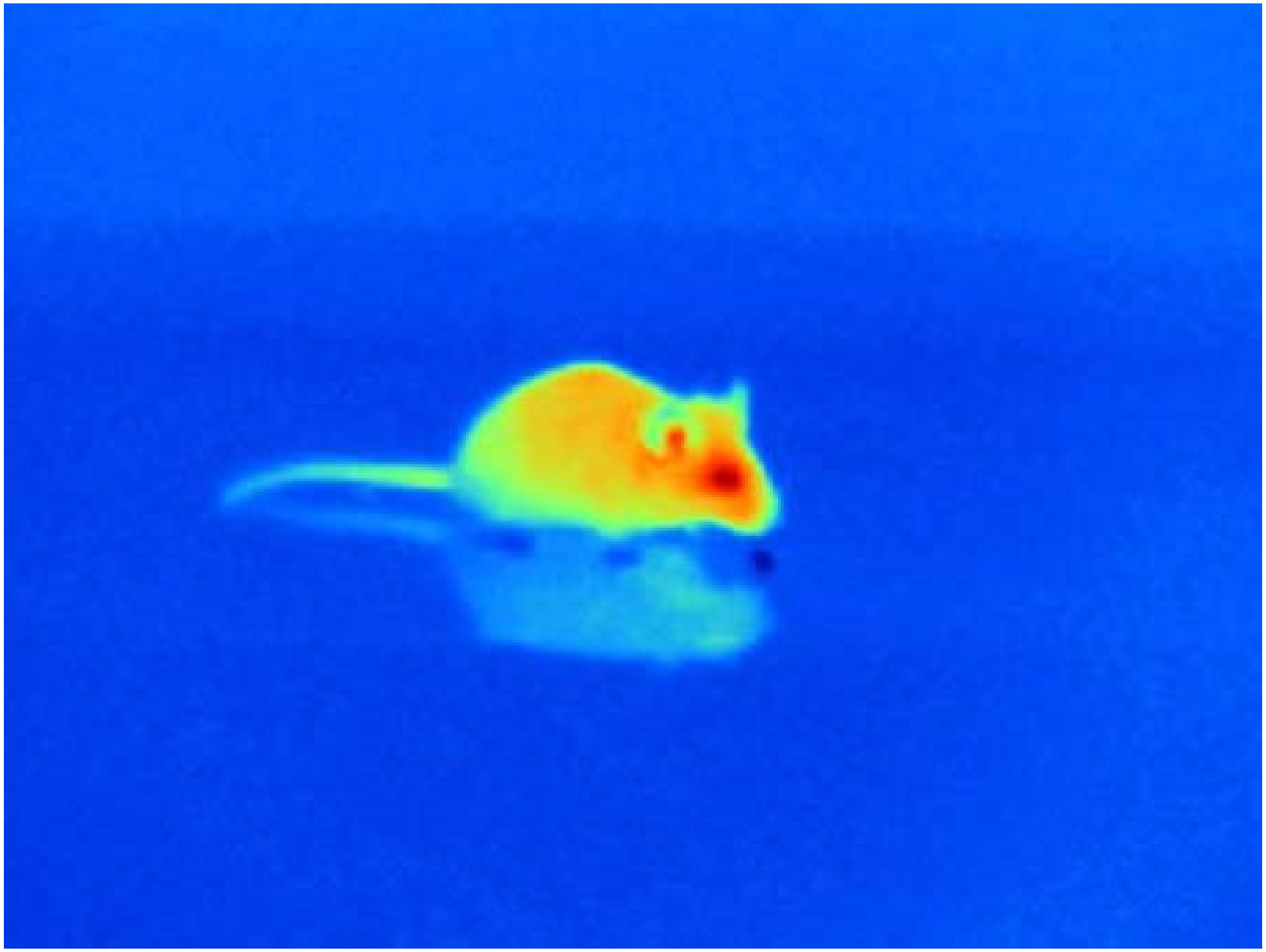
1. Jays remember the past events, and adjust their present behavior to avoid potential consequences in the future (pilfering).

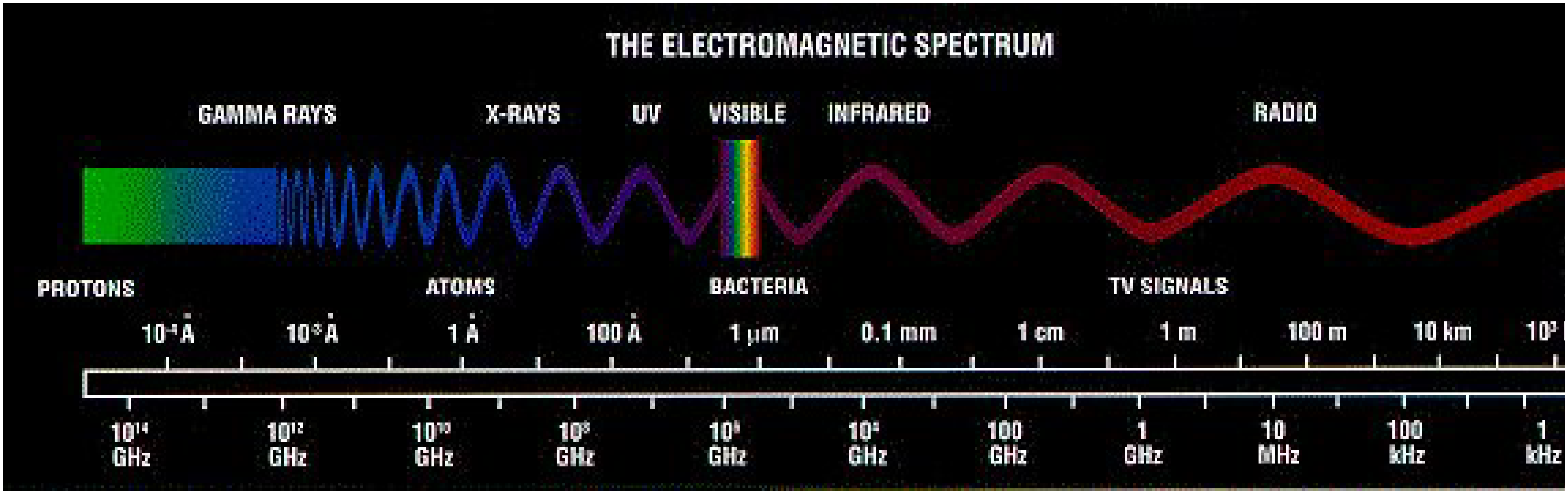
2. The jays transferred their previous experience of being a pilferer to the current situation in which their own caches might be stolen.

3. Episodic memory and future planning

Foraging strategy III

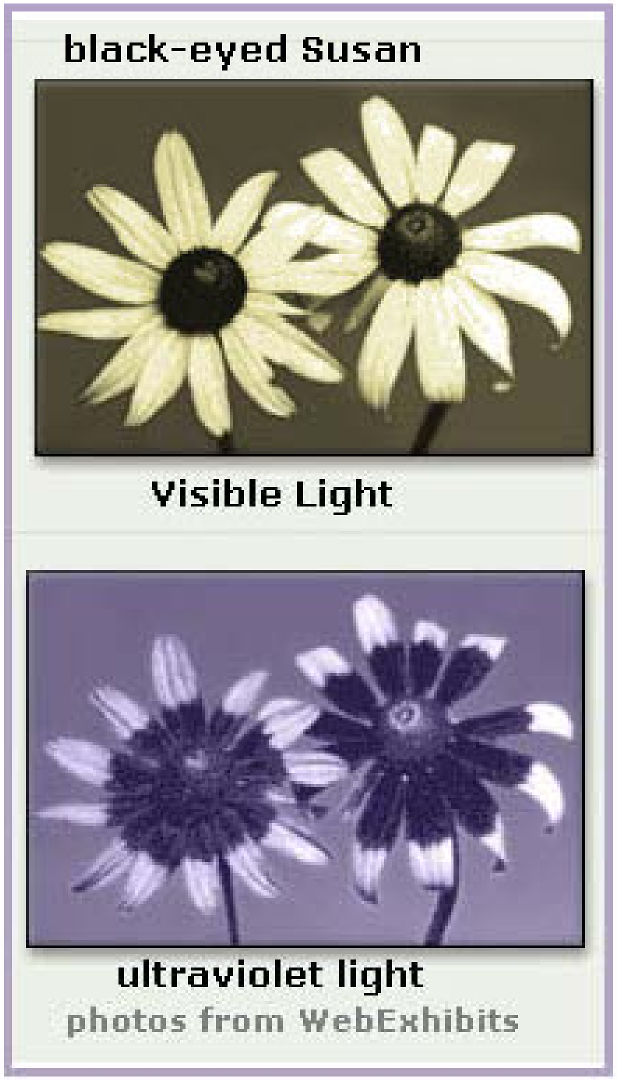
Infrared heat-sensing

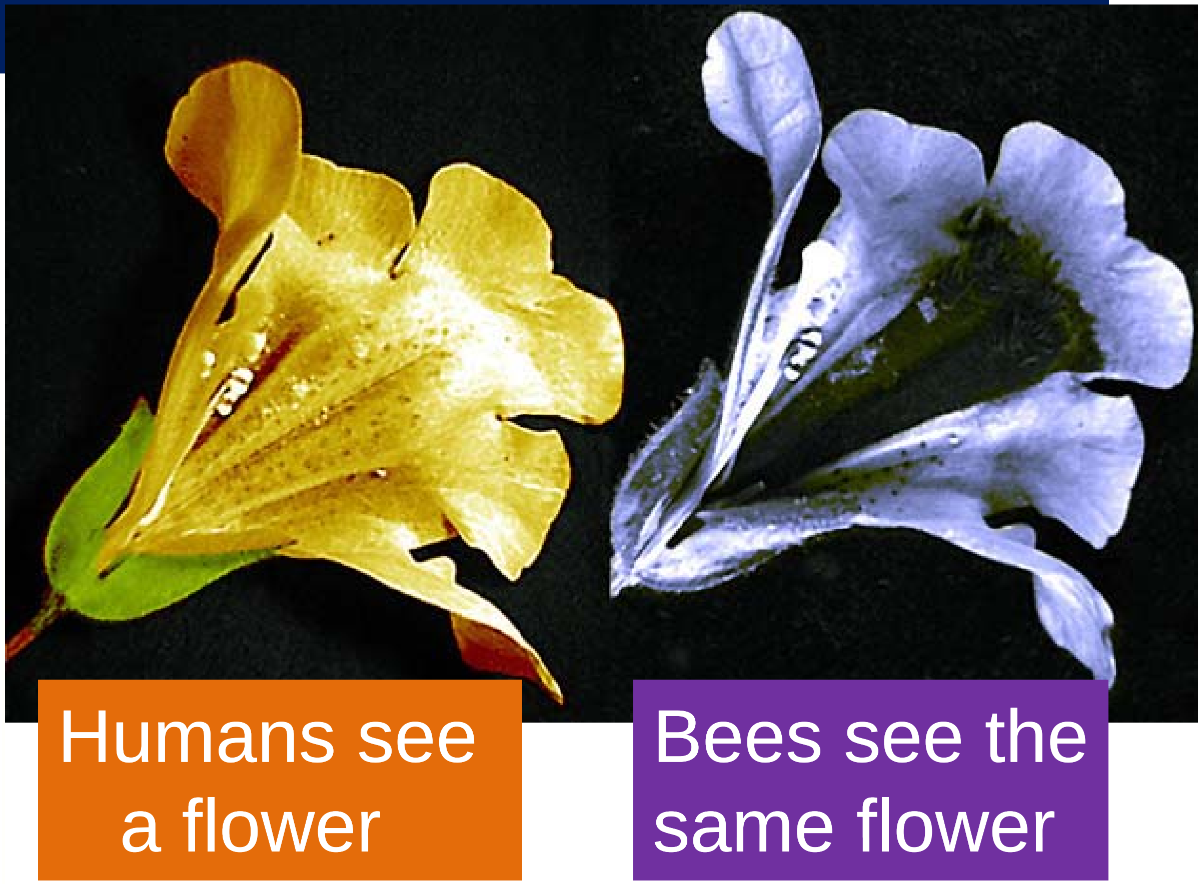




Our eyes are detectors which are designed to detect visible light waves. There are many forms of light (or radiation) which we cannot see with our eyes. Actually we can only see a very small part of the entire range of radiation called the electromagnetic spectrum .

Many animals can see ultra-violet light (UV light)





Humans cannot see UV light

Some animals can see infrared light

Vampire bats

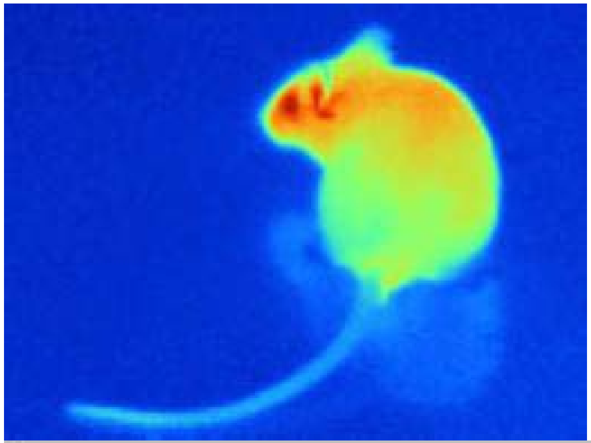
Rattlesnakes

Pit vipers, Pythons

Bed bugs

They all employ **infrared detection** to help locate their 'warm-blooded' prey

Pit vipers can see infrared light



Infrared-sensing pit organs in rattlesnakes

Heat-sensing (infrared) vipers

Pit vipers detect infrared radiation heat emitted by warm-blooded animals

trigeminal neurons in the pit organ sense the heat, signal to the brain →

TRPA1 gene is very active in these neurons much more heat sensitive than the same gene in other snakes lacking the pit neurons.

TRPA1 gene is also highly expressed in trigminal neurons in the pit organ of Boas and Pythons. but not in other snakes lacking pits

Vampire bats detect infrared radiation heat emitted by warm-blooded animals

trigeminal neurons in the sensory pits (around the nose, sense the heat, signals to the brain)

TRPV1 gene is very active in these neurons much more heat sensitive than the same gene in other fruit bat trigeminal neurons

TRPV1 gene does not highly express in other fruit bats lacking pits, not sensitive to heat

Take home message:

To adapt for detecting infrared heat,

Several groups of animals use the pre-existing gene that is used for other purposes (chemical irritants…) shared by many animals but modify the structure and increase the level of expression in specific organ (sensory pits)– endow the animals with sensitive infrared detectors.

“Evolution of new abilities does not necessarily require evolving new genes, but use new variations of very old genes”

Foraging strategy III

Tool using/
Tool making

New Caledonian Crows

Corvus moneduloides

Dr Gavin Hunt

Dr Russell Gray

Dept of Psychology

The University of Auckland

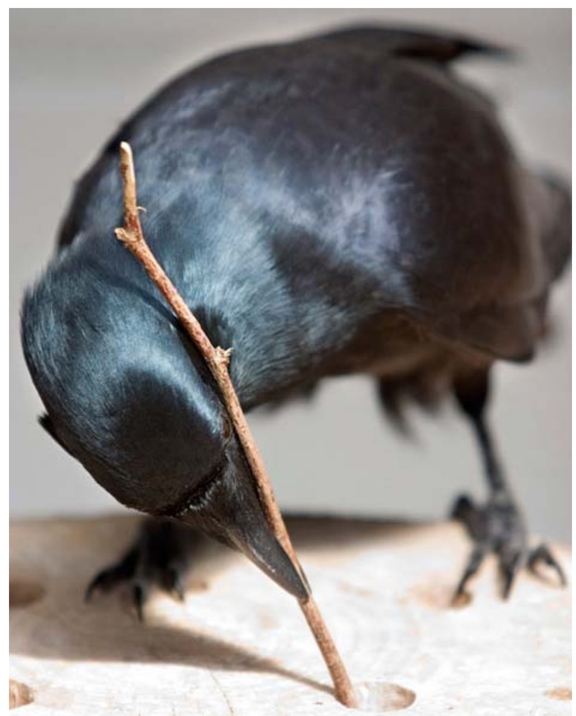
Auckland, New Zealand

NewScientist

Crow uses sequence of three tools

Why do <u>New Caledonia</u> crows have evolved such intelligence of too-using?

But not other species of crows?



Keys: 1. ecological needs (live in forest; feed worms in the trees)

2. bigger brain

3. unique social structure

Most crow species: Group living

New Caledonian crows: Nuclear family living: strong sexual pair-bond, extended and strong family bonding.

-Parents train the juveniles with food as reward, take 3 years.

Let your offspring have an extended childhood in a stable and loving home, with positive reinforcement.

Summary: Strategies of animal feeding behavior

1. Echolocation – bats, dolphins
2. Acquire information from companions – osprey
3. Symbolic language – honeybees
4. Deceiving preys – spiders
5. Food caching – jays, squirrels
6. Infrared sensing heat of preys
7. Tool using – chimps, crows

Optimal foraging theory

Optimal foraging theory

Foraging decisions should be optimal in the sense of maximizing the fitness of the **decision maker** – maximize the **benefit/ cost** ratio.

Northwestern Crows foraging on Whelks

Optimal Foraging Behavior

- A foraging crow has many decisions to make:
  - Where should it search for food?
  - At what time of day?
  - For what prey?
  - How long should it spend trying to process the prey that it has found?

Observations

- Crows picked up large whelks (snails) about 3.5 – 4.4 cm long
- They flew up about 5 meters to drop their chosen whelk
- They kept trying until the whelk broke, even if many flights were required (One crow took 20 drops to open one whelk.)
- Do the birds' behavior reflect **Optimal** decisions (*maximizing whelk flesh per unit time foraging)*?

- can a crow minimizes its expenditure of energy to feed on whelks?

Optimality Hypothesis predictions:

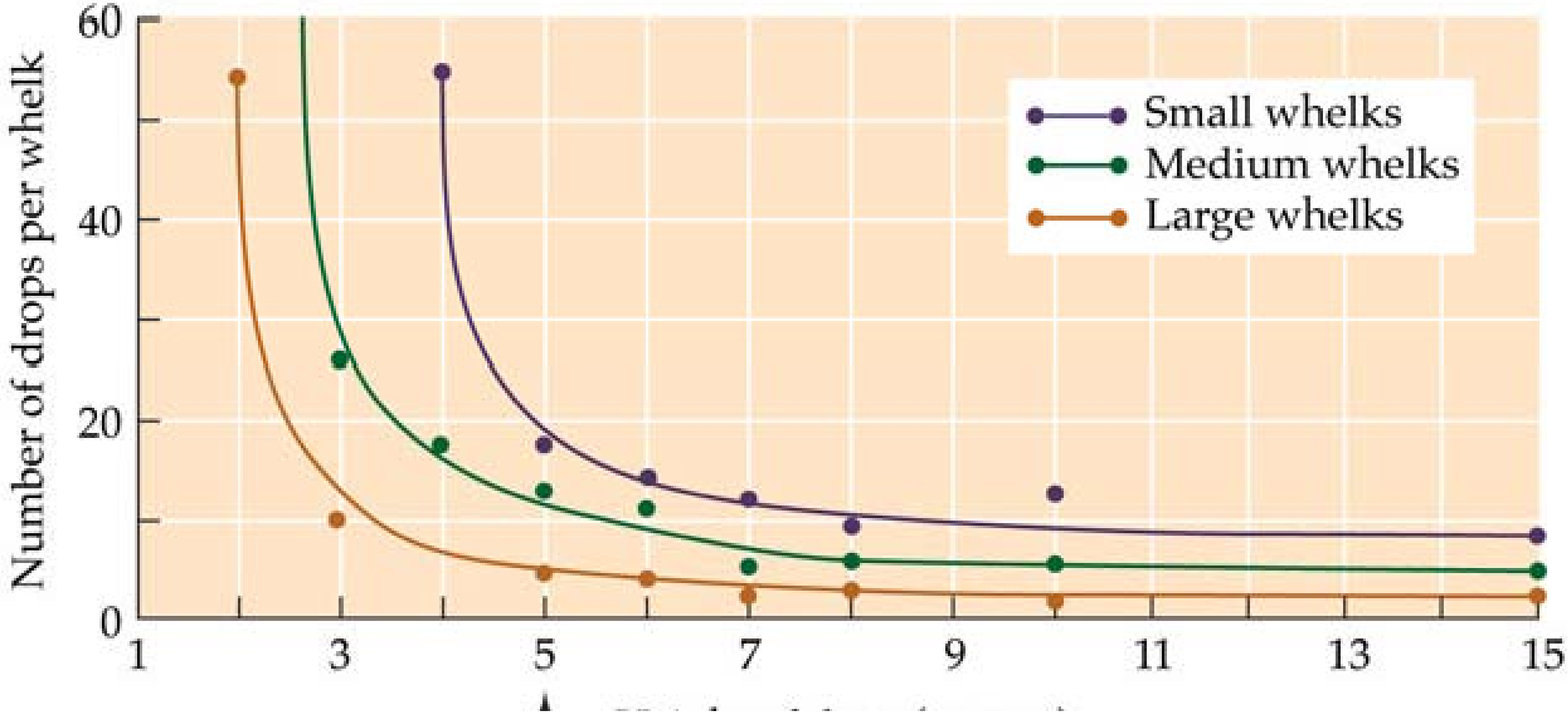
(why drop the whelks at 5m height? we assume 5m is the optimal height, they maxmize benefit/cost to getting food)

- Large whelks should be more likely than small ones to shatter after a drop of 5 meters.
- If 5-m is optimal height, then drops of less than 5 m should yield a reduced breakage rate, whereas drops of much more than 5 meters should not greatly improve the chances of opening a whelk.
- The probability that a whelk will break should be independent of the number of times it has already been dropped.

Crows drop the whelks at 5-meter high seems to be an optimal decision

Large whelks are more likely than small ones to shatter after a drop of 5 m.

drops of less than 5m should yield a reduced breakage rate, whereas drops of much more than 5 m should not improve the chances of opening a whelk.



Feeding strategy by Japanese crows

Optimal foraging theory II

Animal should choose food items that contribute the most to their reproductive success (ideally…)

Food selection by howler monkeys

(1) The more common a tree species, the less likely the monkeys were to feed on its leaves, they spent more time searching out the scarcer species.

(2) They preferred the scarcer, smaller new leaves to the more abundant, larger mature leaves.

(3) The monkeys often ate only the petiole and dropped the larger leaf blade (wasteful?)

It turns out….

The most common tree species had leaves loaded with alkaloid poisons, or indigestible tannins.

Among the scarcer, preferred tree species, howlers sought out just those individuals with lower levels of alkaloids and tannins.

New leaves contain more water, less nonnutritive fiber than mature leaves do.

Monkeys eat the leaf part (petiole), that is lowest in toxins while discarding the more poisonous leaf blade


Red-and-green macaw

Red-and-green macaws eat clay:

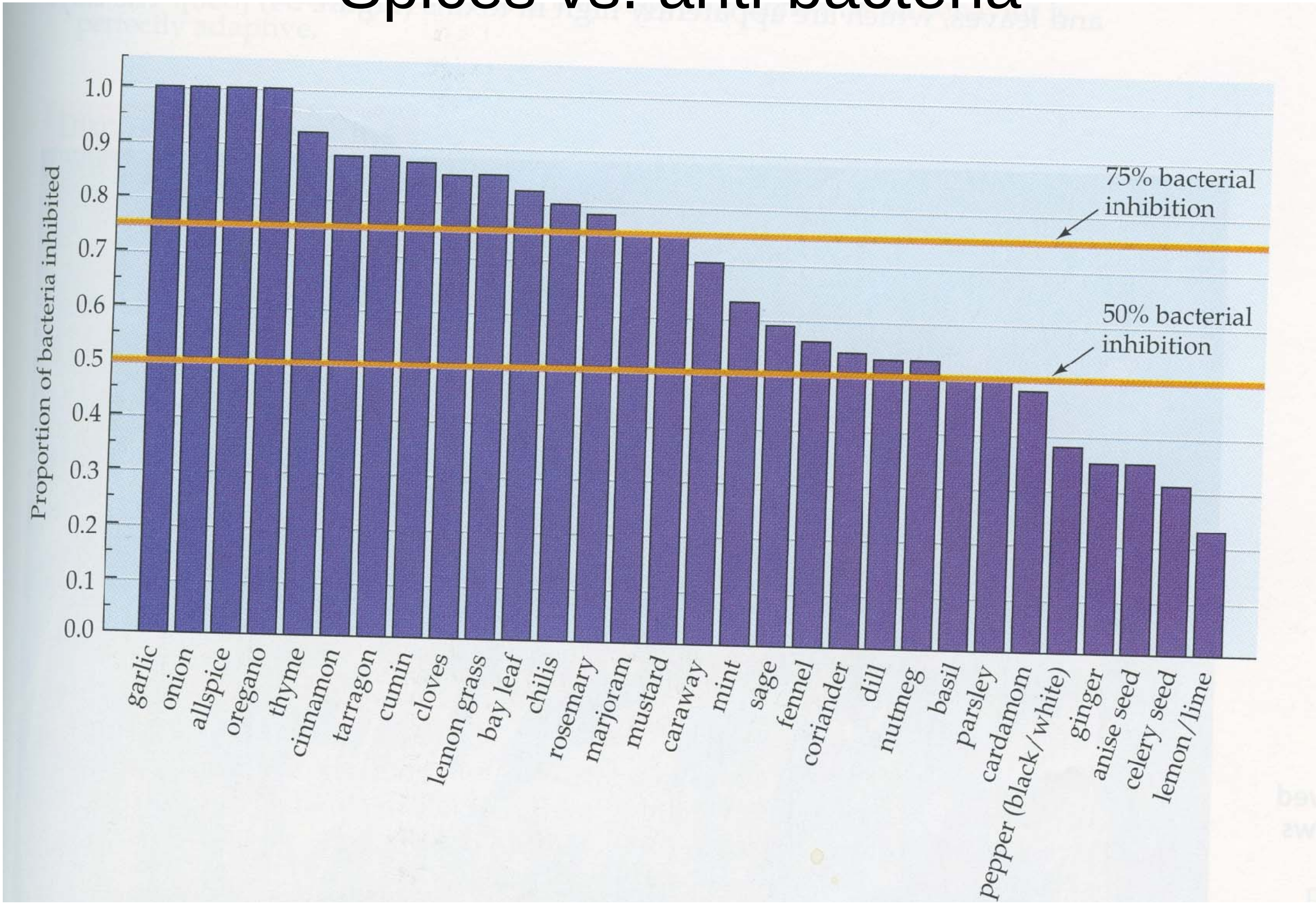
They feed on certain seeds, unripe fruits, leaves (high in toxins, alkaloid)

Clay → detoxification of toxins and alkaloid

Why do humans consume spices?

Nutritive value is low, but we like it

Spices vs. anti-bacteria



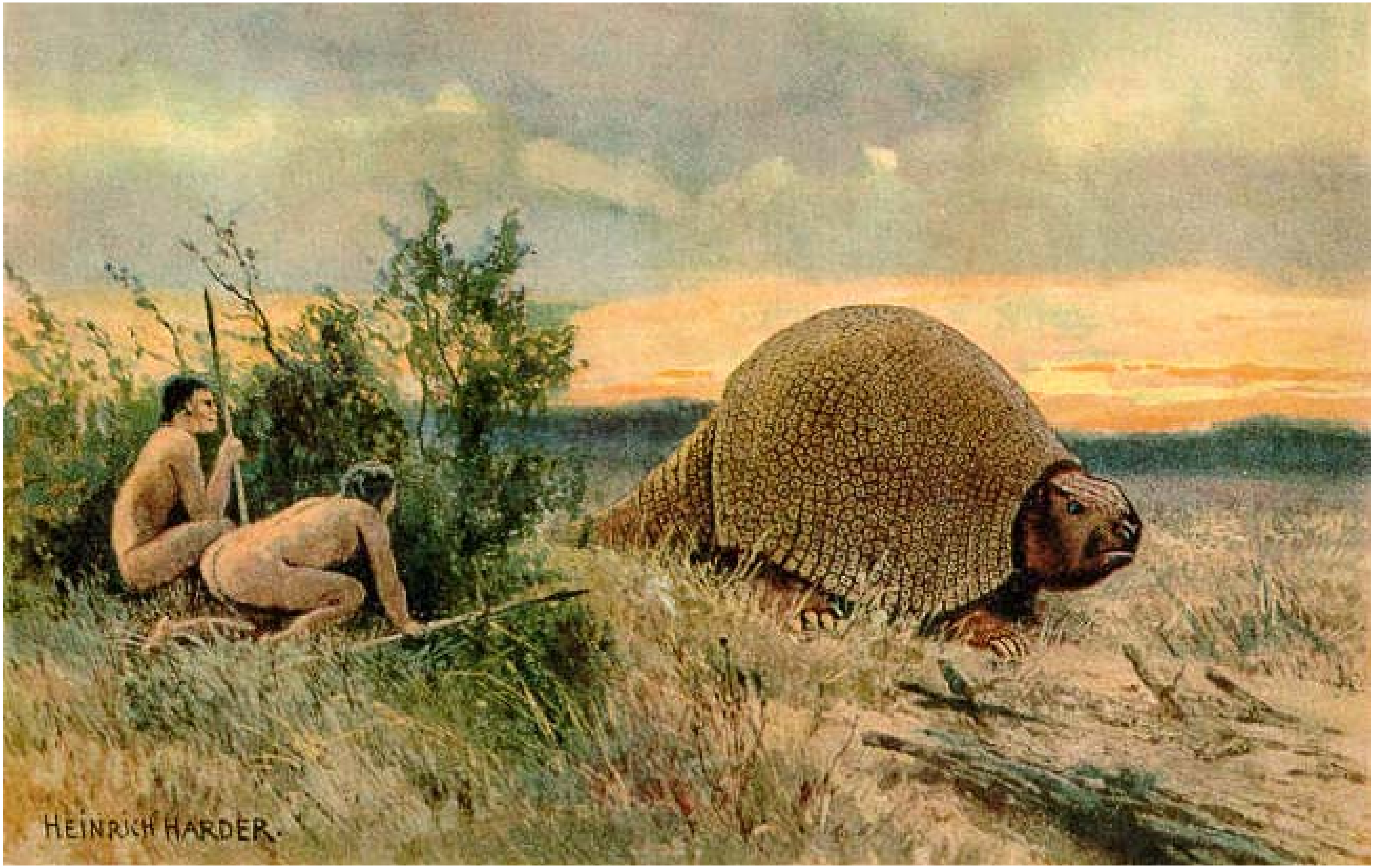
Why do humans consume alcohol? The origin?

Primates become drunk eating ripe fruits.

U.S. Fish and Wildlife

"…..occasionally a cedar waxwing will become drunk or even die from eating berries that have fermented….."

The fattest ape - Omnivore



The Fattest ape : human fatness

-Humans have more fat, to store energy, great advantage during food shortage; for brain development during childhood

-Neanderthals: Carnivorous
Large metabolic demands: 4000 calories a day
When food (meat) is scarce → extinct